SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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JANUARY 1958—VOL. 30, No. 1

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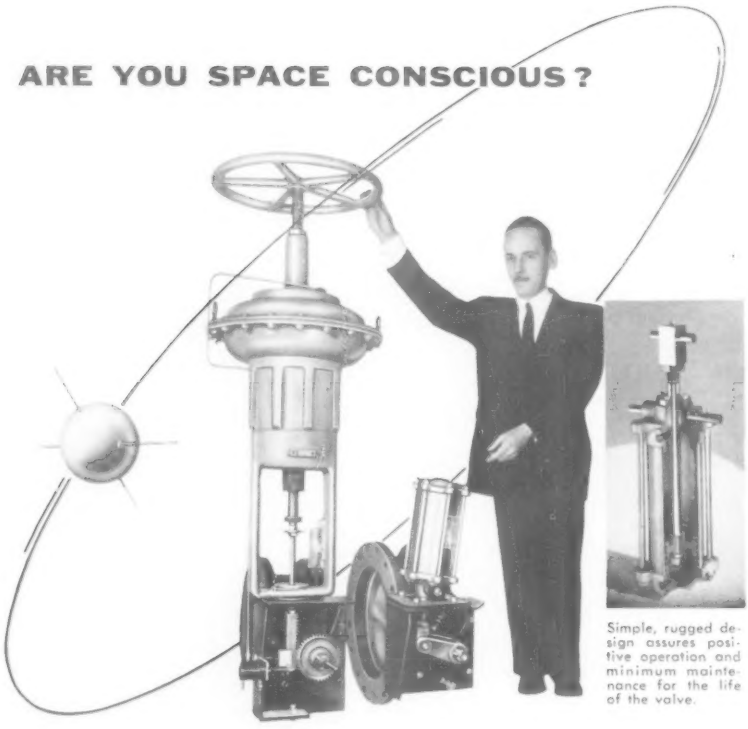

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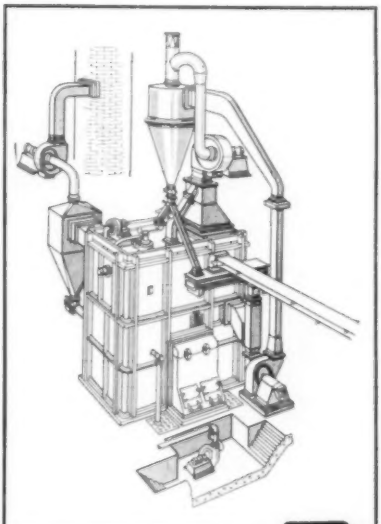

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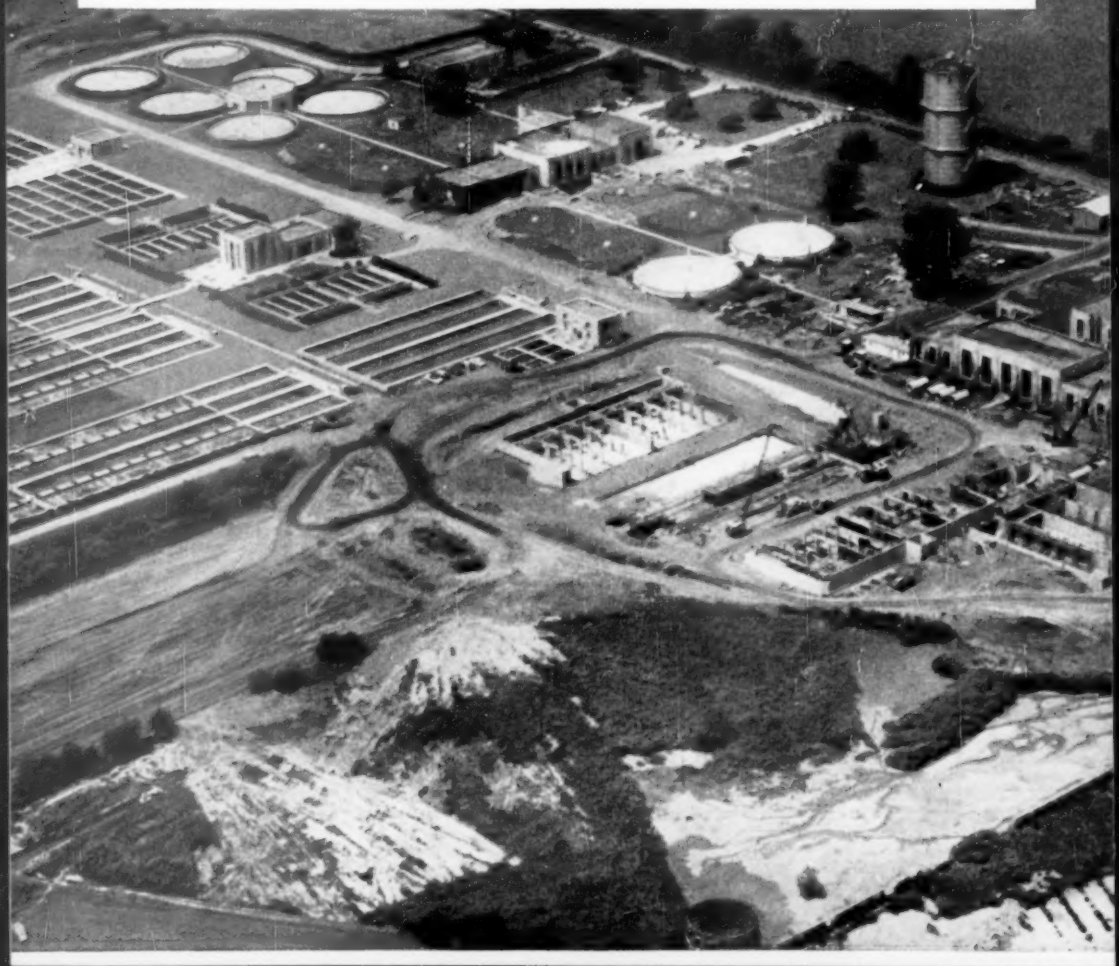

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Association	*Place*	*Time*
New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza New York City, N. Y.	Jan. 22–24, 1958
Utah Sewage and Industrial Wastes Assn.	Univ. of Utah Salt Lake City, Utah	Feb. 10, 1958
Texas Water and Sewage Works Assn.	Texas A & M College College Station, Texas	Mar. 2–7, 1958
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 12–14, 1958
Kansas Sewage and Industrial Wastes Assn.	Lamer Hotel Salina, Kans.	Mar. 12–14, 1958
Montana Sewage and Industrial Wastes Assn.	Florence Hotel Helena, Mont.	Mar. 20–22, 1958
Arkansas Water and Sewage Conf.	Univ. of Arkansas Fayetteville, Ark.	Mar. 24–26, 1958
California Sewage and Industrial Wastes Assn.	Hotel Stockton Stockton, Calif.	Apr. 23–26, 1958
Virginia Industrial Wastes and Sewage Works Assn.	Hotel Roanoke Roanoke, Va.	Apr. 28–29, 1958
Alabama Water and Sewage Assn.	Ala. Polytechnic Inst. Auburn, Ala.	June 9–11, 1958
Ohio Sewage and Industrial Wastes Treatment Conf.	Com. Perry Hotel Toledo, Ohio	June 18–20, 1958
Michigan Sewage and Industrial Wastes Assn.	Charlevoix Hotel Charlevoix, Mich.	June 23–25, 1958

THIRTY-FIRST ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
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Sheraton-Cadillac Hotel, Detroit, Michigan
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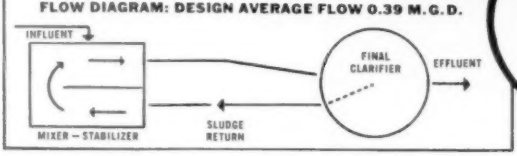

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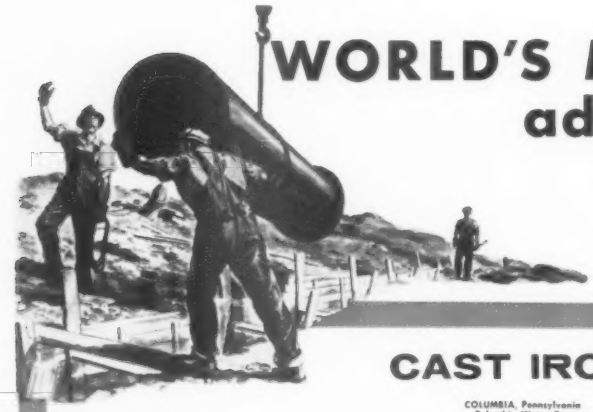

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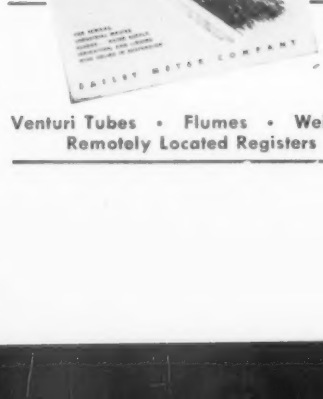

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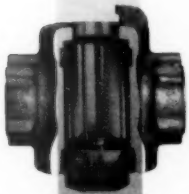
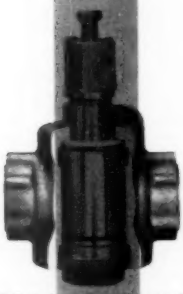


Smooth bearing-surface in body



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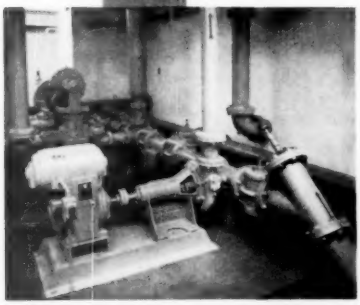

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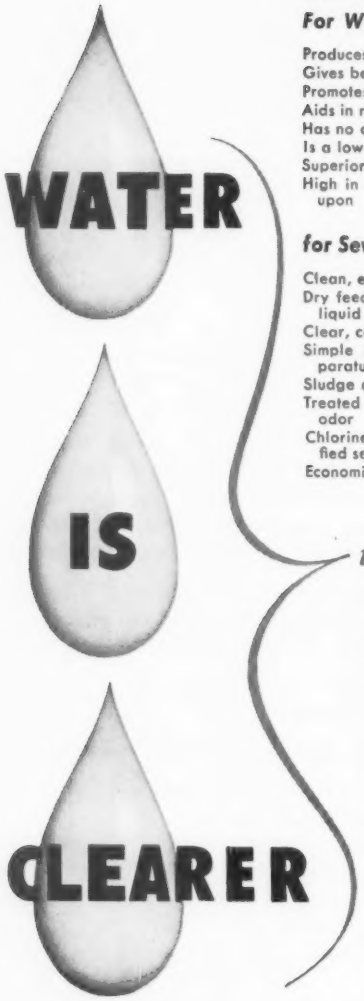

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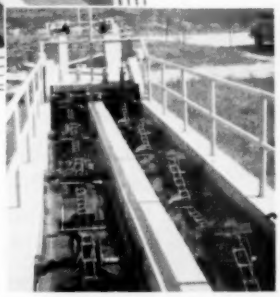

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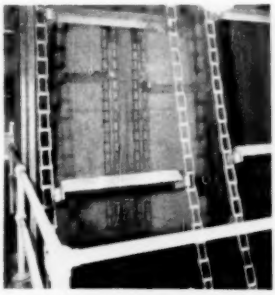

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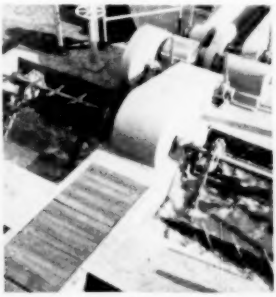

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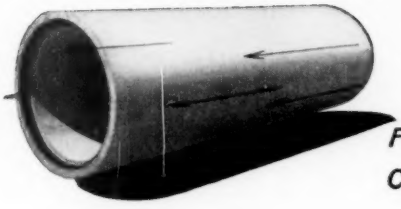

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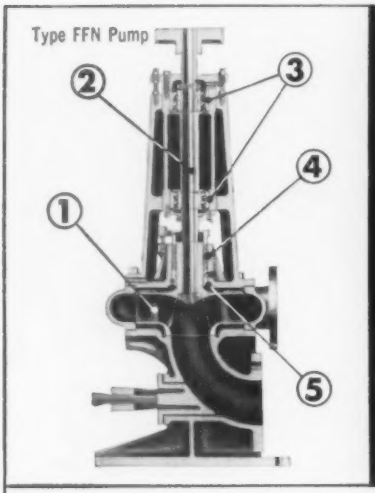

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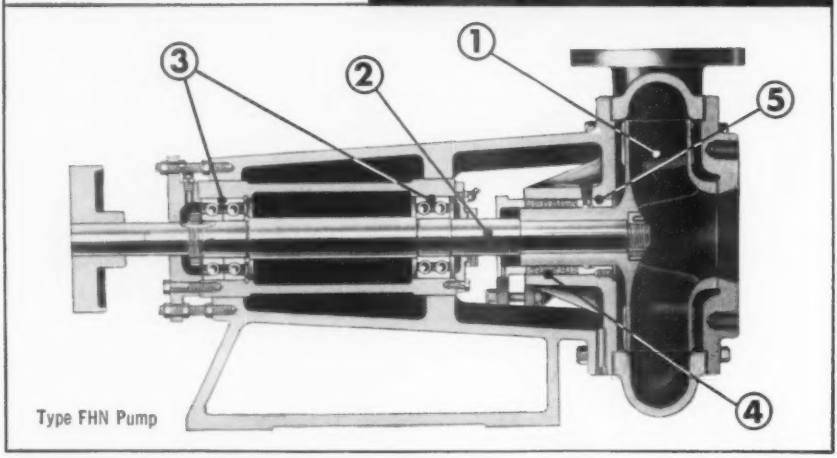

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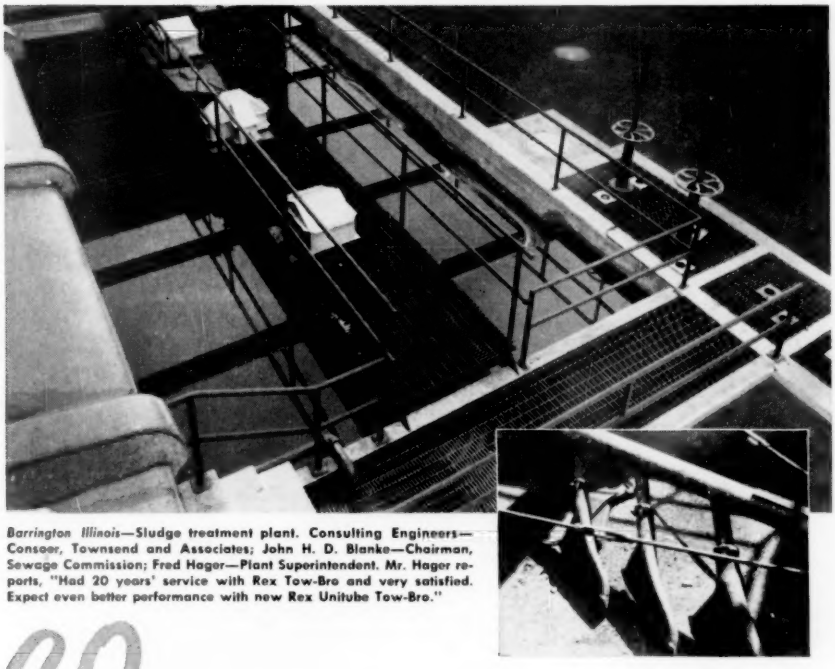

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 30 | January 1958 | Number 1

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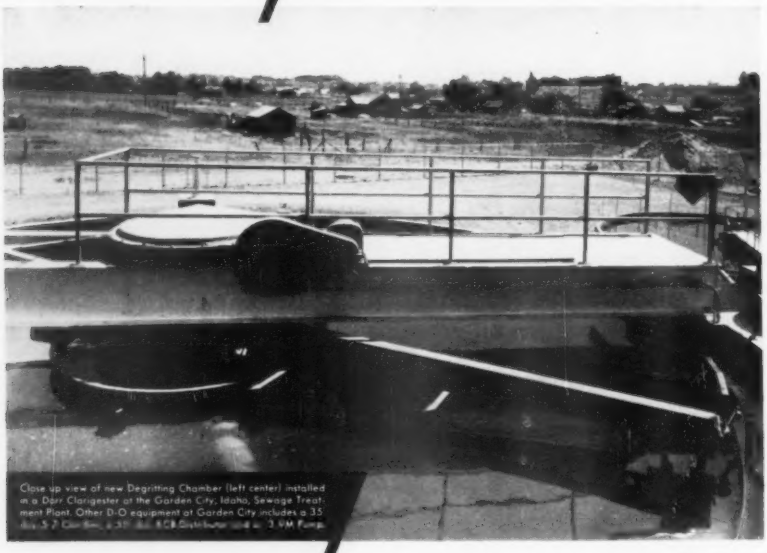

Close up view of new Degritting Chamber (left center) installed on a Dorr Clarigester at the Garden City, Idaho, Sewage Treatment Plant. Other D-O equipment at Garden City includes a 35' dia. S-2 Clari-Rim, a 37' dia. ECI Distributor and a 2 VM Pump.

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Sewage Works

MOVEMENT OF COLIFORM BACTERIA THROUGH POROUS MEDIA *

By R. B. Krone, G. T. Orlob, and Carl Hodgkinson

Respectively, Assistant Research Engineer and Assistant Professor of Civil Engineering, University of California, and Chief, Water Pollution Control, Kansas State Health Department, Topeka, Kans.

Rising costs of development of new or expanded surface water supplies and the critical overdraft of groundwater resources, particularly in certain areas of the western United States, have focused the interest of sanitary and hydraulic engineers on problems attendant to the reclamation of degraded surface waters. Proposals for the artificial recharge of depleted underground supplies with excess surface runoff, industrial wastes and cooling waters, and domestic sewage are receiving much attention. In a few instances sewage spreading on permeable surface soils and direct injection by pumping into subsurface aquifers have been successfully applied with beneficial results. However, such undertakings are often instituted without a full appreciation of their consequences on water quality—in particular, bacterial contamination.

Introduction of domestic sewage into potable ground water poses a number of special problems of particular concern to the sanitary engineer responsible for maintaining water quality and protecting the public health. What degree of bacterial removal may be expected after a distance of travel through a medium? What is the nature of movement of bacteria? How long will bacteria survive under the conditions of waste-water reclamation? These are all fundamentally important questions which should be answered in order to insure intelligent decisions consistent with the best interest of both water reclamation and the health of the people.

Unfortunately, answers to these questions are not available in the published literature, or from the experience of practicing engineers and public health officials. Much information that has been published or is otherwise available dates back to early experience in pit privy and latrine trench design and is somewhat limited in its applicability to modern waste water reclamation. It is possible, however, to profit by these experiences and to use them as bases for further exploration into the fundamental problems of bacteria movement underground.

The basic objective of the investigations reported in this paper is the delineation of the fundamental behavior of coliform bacteria during their movement into and through a porous media system. The results of field investigations for the verification of fundamental removal relations will be presented in a subsequent paper.

Literature Review

Several comprehensive investigations on problems associated with field-scale recharge of sewage, either by surface spreading or by direct injection into

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

underground water-bearing strata, have been conducted by the University of California within the past several years. In each case the published report includes a complete review of pertinent literature and a supplementary bibliography on the general area of research. It was not the intent of this investigation to duplicate that effort and the reader is referred to these publications (1)(2) for much of the historical background in the general field of pollution travel.

It is significant to note, however, that such research as was specifically devoted to the problem of bacteria travel prior to 1950 was largely qualitative in nature and provided little information facilitating an understanding of fundamental removal mechanisms. For example, Kligler (3) who studied the problem of contamination of rural ground water supplies through the medium of the pit privy reported that bacteria were able to move through ". . . a column of 2 ft of porous soil. . . . In denser soil they failed to penetrate through 1 ft." In field studies, near pit privies or near tile pipes from septic tanks, contamination extended downward to a depth of 3 to 5 ft, and laterally only about 3 ft. Stiles, Crohurst, and Thompson (4) in an investigation of pollution from latrine trenches at Fort Caswell, N. C., noted that bacteria traveled at nearly the rate of ground water near the trench but that the rate of travel diminished with time. A total travel of 232 ft in 645 days through a uniformly fine sand, having an effective size (E. S.) of 0.14 mm and a uniformity coefficient (U. C.) of 1.9, was observed.

Caldwell and Parr (5) and Caldwell (6)(7)(8) reported on extensive studies of ground-water contamination from bored hole latrines. They observed that bacterial travel was a function of the characteristics of the medium and that the accumulation of sewage solids and bacterial slimes in the medium produced a "defense" to bacteria penetration. A regression of the pollution front was observed to accompany an increased solids accumulation. Ultimate bacteria travel during the wet season was noted as about 80 ft in a sandy soil (E.S. = 0.068 mm, U.C. = 5.2).

A number of other lesser investigations of pollution travel have also been reported in the literature (9)(10)(11)(12) but for the most part these were without the advantage of careful control or planning. Consequently, interpretation of results with a view to illuminating the understanding of the fundamentals of bacterial movement through porous media is difficult. Wherever, in the ensuing papers, these investigations prove applicable to a point under investigation they are discussed in detail. Similarly, the literature which is pertinent to certain phases of the research presented herein, but less generally applicable to the entire field of pollution travel, is treated elsewhere.

Preliminary Investigation

In an exploratory study, primary settled sewage was infiltrated into 4-in. diameter columns of Oakley sand, a comparatively permeable agricultural soil. Provision was made for extraction of the percolant at various depths below the soil surface. It was evident from the results of these experiments that not only was the surface stratum of the soil the limiting horizon for movement of sewage particulates, as had been previously established (13)(14), but also that it greatly restricted the entrance of bacteria into the soil.

It was noted that the problem of bacterial removal was resolvable into two distinct areas of investigation; one concerned with the effect of the surface stratum and the other concerned with behavior of bacteria in the subsurface regions in the absence of particulate matter. Near the surface of the soil an abrupt drop in coliform bacteria numbers in the percolant occurred; but farther down in the column, below

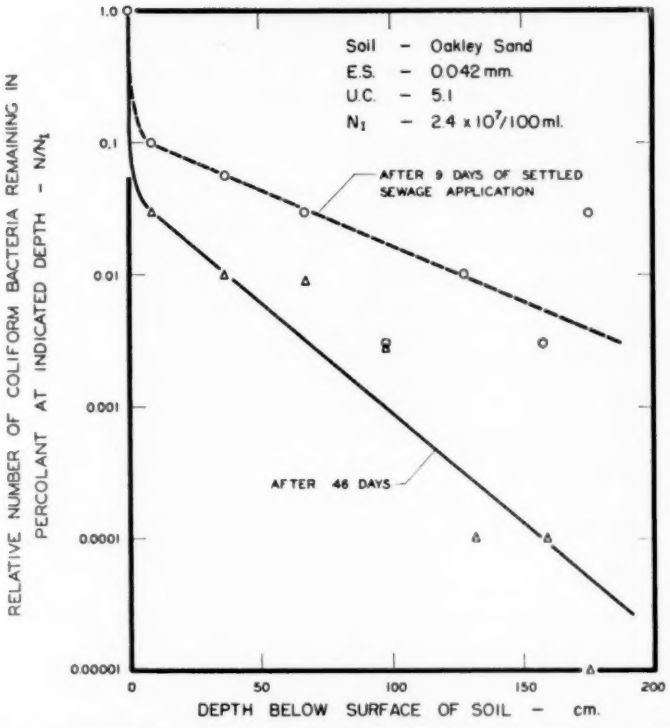

FIGURE 1.—Removal of coliform bacteria during percolation of settled sewage through Oakley sand.

the first few centimeters of clogged surface stratum, the decrease appeared to be a logarithmic function of the distance traversed by the contaminated percolant. Two typical series (Figure 1) show a clear division between these zones of removal.

To avoid the limitations imposed on the preliminary studies by the use of ordinary domestic sewage and natural porous media it was decided that, where practical, uniform sieved materials and pure culture bacteria would be employed.

Four sand separates obtained by sieving a fine sandy loam were used. These separates had median sizes of 0.11, 0.040, 0.019 and 0.0063 cm, determined microscopically. The media were placed in lucite columns of 2- to 4-in. diameter filled with sterile washed sand to depths appropriate for the particular investigation. For the finer sands a 6-mm layer of 1.1-mm sand was used as an underdrain and support.

Columns were assembled by pouring dry sand continuously while tapping the side of the column with a mallet. Reproducible porosities of 0.43 to 0.45 were easily achieved by this technique and the continuous admission of sand prevented stratification. Initial wetting was accomplished by suddenly admitting water to the top of the sand while applying partial vacuum to the base of the column. A uniform wetted front then moved down the column and provided thorough wetting of the sand.

The *E. coli* for investigation of subsurface movement were isolated from a sewage inoculum on eosine methylene blue agar, and were grown on 1/10 standard strength lactose broth for 18

hr. before each experiment. Ten milliliters or more of this culture was then diluted to 20 l with distilled water for application to a sand column. Four to 10 g of sodium chloride were also added to serve as a chemical tracer for measuring the water movement through the sand.

Theoretical Considerations

It may reasonably be assumed that any mechanism responsible for the separation of bacteria, or suspended particulates, from water flowing through porous media will remove a fraction of the bacteria passing an increment of length in which that mechanism is operative. Such removal is described by the relation

$$\frac{dn}{dL} = -F n \quad \ldots\ldots\ldots (1)$$

in which n is the number of bacteria per unit volume of percolant, L is the distance traveled by the percolant, and F is the fraction removed per increment of distance traveled. Integration of Eq. 1 and satisfaction of the boundary condition yields

$$n = n_0 e^{-F L} \quad \ldots\ldots\ldots (2)$$

in which n_0 is the bacterial concentration at the media interface ($L = 0$).

Hall (15) proposed a discontinuous function of removal with distance traveled through the medium. If removal occurred around each contact zone, or in each pore, the concentration at the exit of each pore after removal of a fraction, F', would be

$$n = n_0(1 - F') \quad \ldots\ldots\ldots (3)$$

or, for a distance L, with pores spaced d^* apart

$$n = n_0(1 - F')^{L/d'} \quad \ldots\ldots\ldots (4)$$

which is closely approximated by Eq. 2 when L/d' is very large.

An increase in the number of bacteria on an increment of media along the path of flow will be equal to the decrease in the total number of bacteria which have passed that increment, or if N_s is the number of bacteria on the soil, and V is the volume of fluid passed,

$$\frac{dN_s}{dL} = V \frac{dn}{dL} + n \frac{dV}{dL} \quad \ldots\ldots\ldots (5)$$

In a column of soil, $\frac{dV}{dL} = 0$, and from Eq. 2

$$\frac{dn}{dL} = -F n_0 e^{-F L}$$

so that Eq. 5 can be written

$$\frac{dN_s}{dL} = -F V n_0 e^{-F L} \quad \ldots\ldots\ldots (6)$$

At the beginning of bacterial penetration, removal is accomplished by two mechanisms—mechanical straining in the portion of the pore opening nearest the grain contacts and sedimentation on grain surfaces within the media pores. Hall postulated that an effective straining site in a pore possesses a cross-sectional area normal to the direction of flow which is approximately described by an isosceles triangle whose base width, D, is the effective diameter of a particle removed from the flow. For spherical grains the fraction of the particles removed per grain layer was found to be

$$F_1' = 35 a_1 \left(\frac{D}{d}\right)^{3/2} \quad \ldots\ldots\ldots (7)$$

in which a_1 is a coefficient used to correct for nonuniformity of flow across the pore opening. Values of a_1 reported by Hall range from 0.038 to 0.063 for filter sand.

The concept of removal of particulates in a porous medium by the mechanism of sedimentation was originally proposed by Hazen (16). If sedimentation follows Stokes' Law, the settling velocity, v, of a particle of diameter, D, is expressed by

$$v = \left[\frac{(\rho_s - \rho_L) g}{18 \mu}\right] D^2 \quad \ldots\ldots\ldots (8)$$

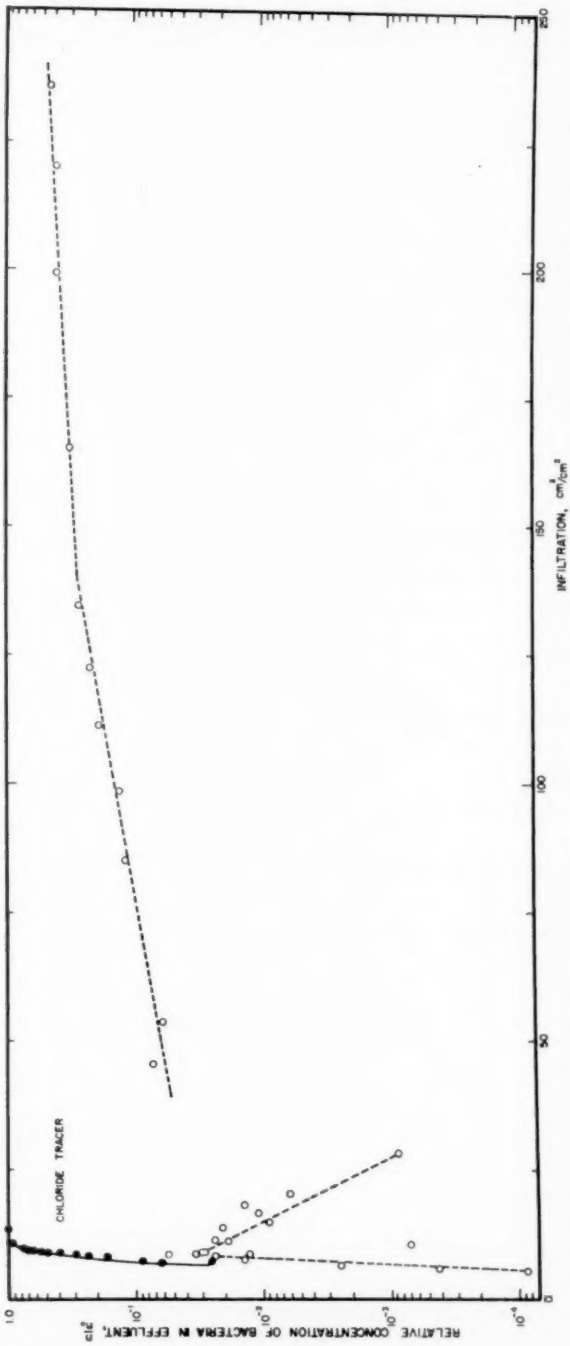

FIGURE 2.—Arrival of *E. coli* through coarse sand; 1.1-mm sand column 18.4 cm long; infiltration rate = 0.83 cm per minute.

For a given set of conditions the term in brackets, including the acceleration of gravity, g, viscosity, μ, and difference in density between solid and liquid, $(\rho_s - \rho_L)$, may be replaced by M. The fraction removed per grain layer F_2', was expressed by Hall as

$$F_2' = a_2 \frac{M\ D^2}{q} \quad \ldots\ldots\ldots (9)$$

in which q is the average pore velocity obtained from Darcy's Law and the effective porosity of the medium, and a_2 is a coefficient relating removal efficiency from horizontal to vertical flow. For vertical flow, a_2 is about 0.1.

For a short period following the application of bacteria-laden water to a porous medium both removal mechanisms (straining and sedimentation) are operative. As demonstrated subsequently, the capacity for removal by straining in the first layer of grains is soon reached, and is thereafter inoperative, or saturated, leaving only sedimentation operative in that region. If the distance over which saturation of the straining sites exists is L_s, the concentration of particles at that or any greater distance is

$$n_L = n_0 e^Z \quad \ldots\ldots\ldots (10a)$$

in which

$$Z = -(F_1 + F_2)\ L + F_1 L_s \quad \ldots (10b)$$

From the increment of the number of organisms required to increase the saturation of straining sites an increment of distance, L_s, can be found to be

$$L_s = \frac{V - V_s}{V_s}\left(\frac{1 - \Sigma F'}{\Sigma F'}\right) \quad \ldots (11)$$

in which V is the volume of fluid passing into the medium per unit area and V_s is the volume having passed when the straining sites in the surface layer of grains became saturated.

Bacterial Breakthrough

An understanding of the characteristics of the straining and sedimentation removal mechanisms in removing bacteria from a contaminated percolant by a porous medium can be obtained by examination of the bacteria concentration-time curves after a given distance of travel through a sand. This "breakthrough" is characterized by (a) the first arrival of a bacterium at the sampling point and an abrupt increase in numbers to a primary peak; (b) a somewhat erratic decline in concentration followed by (c) logarithmic increases to a maximum level; (d) the maximum level is sustained until (e) a final decline in numbers occurs. The first three phases are typified by the results of an experiment on 0.11-cm sand shown in Figure 2. Characteristics of the maximum plateau and the subsequent decline are illustrated in Figures 3 and 4, which report the results of investigations on a 0.019-cm sand fraction.

The first abrupt rise in bacterial numbers in the column effluent is caused by the bacteria that successfully escape the influence of either of the two removal mechanisms. It is significant that in every instance where detectable contamination was observed, bacteria appeared to arrive before the chemical tracer (chloride). This anomalous result can be accounted for by the difference in sensitivity of the analytical techniques for assaying the samples, and the comparatively short travel distances employed in the experimental columns.

Straining Mechanism

After the first arrival of bacteria the concentration in the column effluents continued to rise to a maximum, after which it fell as bacteria accumulated in the straining sites, suggesting that the accumulating bacteria enhance the straining removal. A condition of mechanical instability of the accumulations in the presence of flowing percolant is soon reached in the surface layer of grains and a cascade of organisms and clusters of organisms follows.

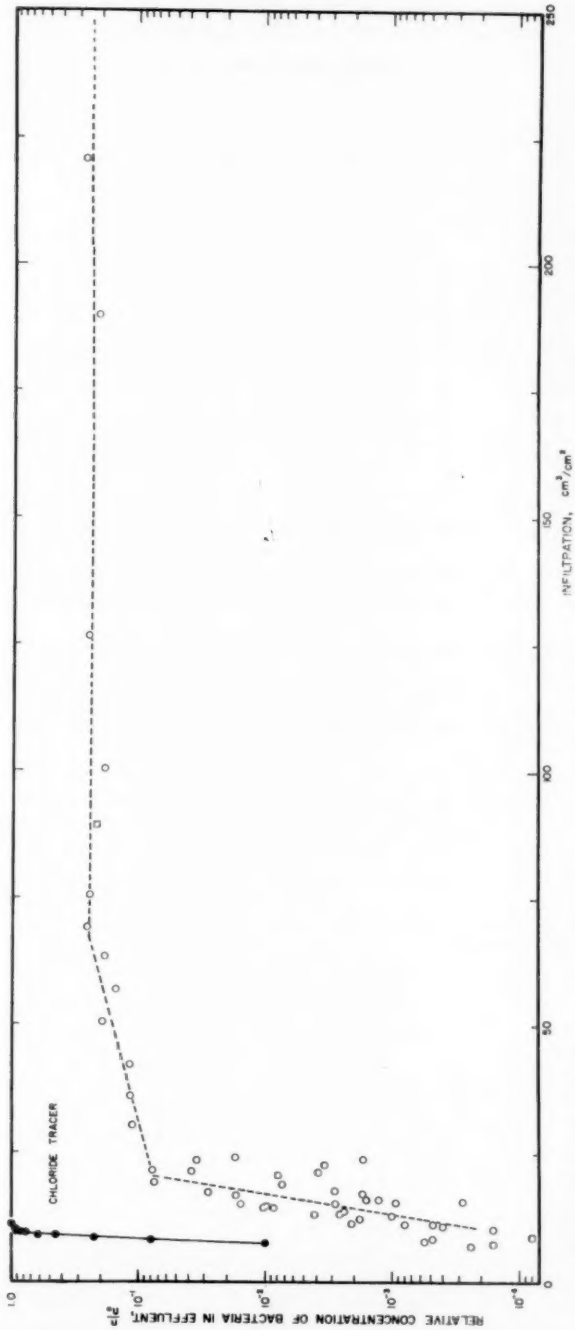

FIGURE 3.—Arrival of *E. coli* through fine sand; 0.19-mm sand column 18.9 cm long; infiltration rate = 1.25 cm per minute.

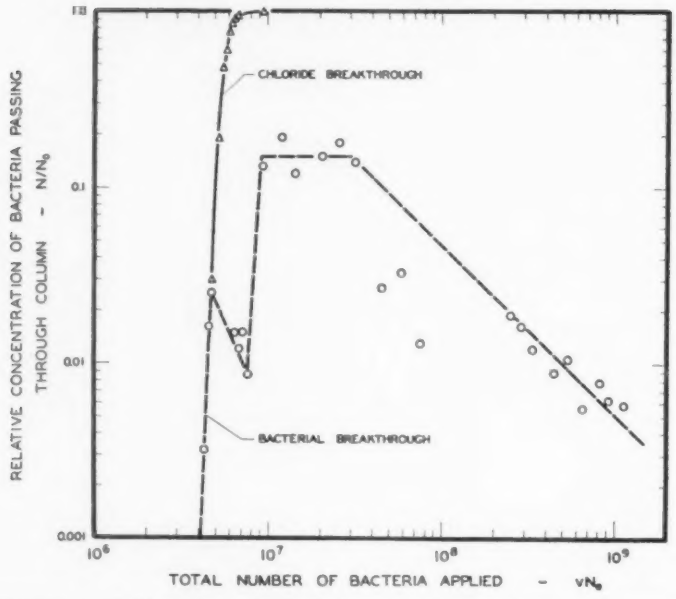

FIGURE 4.—Coliform bacteria breakthrough and saturation in 0.19-mm sand, saturated flow.

The cascade causes a very rapid advance of the front of saturated straining sites, shown by the steep logarithmic increases in Figures 2 and 3. After the cascade is dissipated a slower, regular advance of the saturated straining site front continues from organisms penetrating the porous medium. The saturated straining sites continue to accumulate bacteria and slough off clusters which are subsequently removed in later straining sites or by sedimentation.

TABLE I.—Straining Particle Diameters from Column Experiments

Sand Size (mm)	F_1	F_1*	Bacterial or Cluster Diam. (microns, μ)
1.1	0.0118	0.91×10^{-3}	9.0
	0.0133	1.02	9.6
0.4	0.164	4.6	9.2
0.19	0.091	1.3	2.0
	0.109	1.4	2.0
	0.096	1.3	2.0
	0.206	2.7	3.2
	0.057	0.8	1.4
0.063	0.46	2.0	0.88
	0.74	3.3	1.2

* Calculated from $F = F'/d'$, using $d' = 0.7d$.

Table I summarizes the results of a number of independent studies of the straining characteristics of several sand fractions. Values of F_1, the fraction removed per unit distance traversed, were determined from the breakthrough curves after correction for the effect of sedimentation. The fraction removed per grain layer, F_1', was computed from the average grain layer thickness, d', taken as 0.7d, from the relation $F_1' = F_1 d'$. The table shows a slight variation of F_1' between sand sizes, which is believed to be due to variations in grain shape. It is of interest to note that the effective diameter of the particles (clusters) decreases with decreasing sand size, down to the approximate diameter of a single bacterium. The value of a_1 was taken as 0.05, the mid-value of the range given by Hall for filter sands.

The results for a column observed under conditions of unsaturated (with water) flow conditions are presented in Figure 5 to show further the characteristics of straining removal. This column was irrigated with a mist of bacteria-laden water and a tension was applied to the liquid phase at the base of the column so that the water traveled as a film over the surfaces of the grains and in the contact zones. When compared with saturated flow in a similar column (see Figure 2), it is at once apparent that the clustering phenomenon and the subsequent cascade are absent. As the straining sites fill, the water film runs over the surfaces of the bacterial accumulations leaving stable saturated straining sites.

Sedimentation Removal

When the capacity for removal by straining has been satisfied over the length of the column, sedimentation alone is operative and the effluent concentration is constant (Figures 3 and 4). Values of F_2 and F_2' were calculated from this constant level of bacterial concentration.

In order to apply Stokes' Law to sedimentation removal it is necessary to evaluate the density of the individual cluster or bacterium which is removed from the fluid. It was noted during the course of the investigation that even the relatively low salt concentrations used as a chemical tracer appreciably affected removal by sedimentation. These experiments indicated that a fluid having a specific gravity of 1.0012 would prevent sedimentation removal. Inasmuch as an individual bacterium has a specific gravity between 1.02 and 1.08, according to Heilbrunn (17), it was apparent that bacteria were being removed as clusters, rather than as individual organisms. The low density of the clus-

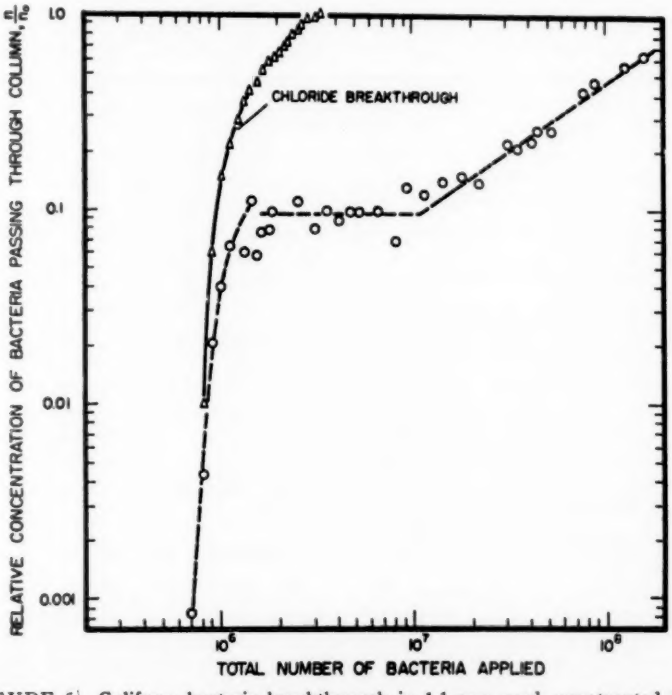

FIGURE 5.—Coliform bacteria breakthrough in 1.1-mm sand, unsaturated flow.

TABLE II.—Diameter of Bacterial Clusters as Calculated from Sedimentation Theory

Sand Size (mm)	q (cm/sec)	F_2'[1]	F_2[1]	Pore Opening[2] (mm)	Cluster Diameter[3] (mm)
1.1	0.0442	0.0035	0.00027	0.16	0.14
	0.0129	0.0085	0.00065		0.11
0.4	0.0446	0.0169	0.00047	0.057	0.056
0.19	0.0244	0.078	0.00101	0.027	0.018
	0.0294	0.102	0.00133		0.024
	0.0358	0.089	0.00116		0.026
	0.0397	0.104	0.00135		0.028
	0.0522	0.127	0.00178		0.038
	0.0786	0.157	0.00202		0.049
	0.229	0.068	0.0090		0.049
0.063	0.0197	2.30	0.0101	0.009	0.010
	0.0462	2.00	0.0088		0.012
	0.0617	2.17	0.00957		0.014

[1] $F' = Fd'$, for $d' = 0.7d$.

[2] For close packed spheres $0.085d$, for orthogonal pack, $0.20d$. Taken here as $d/7$.

[3] Calculated from Eq. 9, with $(\rho_s - \rho_L) = 0.0012$, $a_2 = 1$ for 1.1, 0.40, and 0.19 mm sands and $(\rho_s - \rho_L) = 0.05$ for 0.063 mm sand.

ters might be partially due to an accumulation of carbon dioxide (a product of bacterial metabolism) within the mass.

If aggregation of bacteria occurs at the straining sites near the soil surface, the size of the free clusters might be determined either by the shearing resistance of the aggregation or by the size of the restrictions between soil pores. If the aggregation was nearly as large as the entrance to a pore, then every cluster would be at least partly within a portion of the flow subjected to removal by settling, and a_2 in Eq. 9 would be nearly unity. Diameters of the aggregations were computed, using this value of a_2 and 0.0012 as the difference between the water and particle densities for the coarser sands, and 0.05 for the 0.063 mm sand. These values are presented in Table II together with the approximate inter-pore restriction diameters, calculated as $d/7$.

Fair agreement between approximate pore opening diameters and cluster diameters can be seen in the Table II. The density of individual bacterial cells were used for the finest sand because the pore opening is roughly equivalent to the length of two cells. Individual cells would be expected to be comparatively free of gas or water entrapment.

Table II also shows, for the 0.19 mm sand, that D increases with velocity, q, to values slightly greater than the maximum pore opening. This was at first believed to be due to variations of a_2 with q, giving apparent variations of cluster diameter. It was found, however, that increasing the flow rate by a factor of nearly three (note the last values for 0.19 mm sand in Table II) did not increase the calculated cluster diameter but did reduce the removal rate. This finding, together with the concurrent increase in the measured values of F_2 with increasing values of q, support the listed values of cluster diameter. It is concluded that the effective cluster diameter increases with q to a maximum determined by the pore openings, and that for values of q above that required for maximum cluster diameter, the removal rate decreases.

Ultimate Removal Capacity

The total useful capacity of a soil column for removing bacteria is approached when the voids in the region of greatest removal become filled. In an isotropic soil this occurs at the soil

surface (where n is greatest) and amounts to clogging by bacterial cells or, in large openings, by discontinued removal. When the voids near the soil surface become sufficiently filled to remove bacteria by straining, additional organisms might be expected to increase the straining removal rate. Figure 4 presents the results of an experiment designed to show this removal phenomenon.

A number of low values were noted before the log-log decrease occurred. An explanation is that a very shallow stratum near the surface became restrictive until the mass of cells in the surface voids was forced through to the next openings. This process continued until the accumulation of cells in soil voids was sufficient physically to restrict the movement of water.

The clogging phenomenon is definitely self-limiting; that is, after clogging of the soil surface has begun, the more rapid removal of bacteria increases the removal rate until the movement of water and further movement of bacteria is very much reduced. If a short depth, L, from the surface is taken as that to which the clogging extends, and it is assumed that after a given number of bacteria fills the voids, F increases with further increases in removed bacteria, N_s, then

$$F = K N_s = K \Delta V n_0 F e^{-F_s L} \quad (12a)$$

and

$$e^{-F L} = \frac{1}{K \Delta V n_0} \quad (12b)$$

and

$$ln \frac{n}{n_0} = - ln K n_0 \Delta V \quad (12c)$$

In porous media having inter-pore openings too large to be bridged by bacterial accumulations or filtered solids, the capacity for removal by sedimentation would simply become saturated, and the saturated front would progress as described for the straining mechanism.

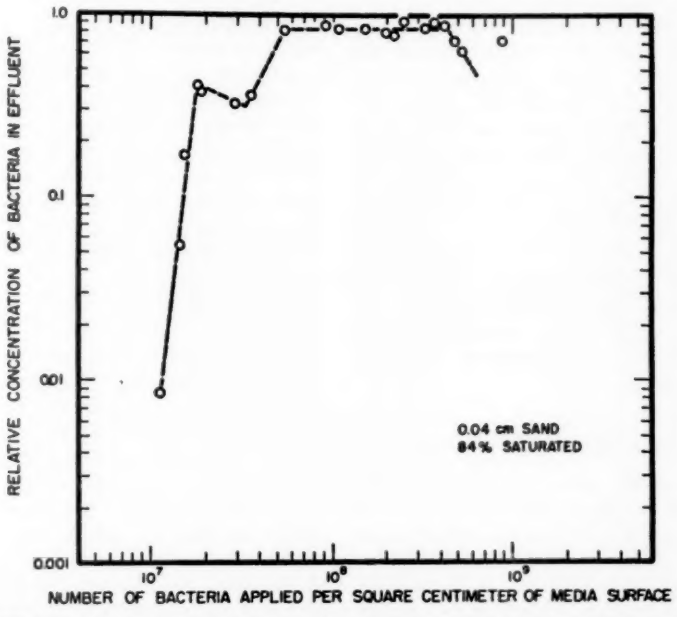

FIGURE 6.—Coliform bacteria in the effluent from a partially saturated sand column.

TABLE III.—Calculated Diameters* for Bacterial Removal in Unsaturated and Saturated Flow Through 0.4-mm Sand

Saturation (%)	F_1	Particle Diameter (μ)	F_1	η	Particle Diameter (μ)
84	0.040	2.0	0.0091	0.0388	12
100	0.164	9.2	0.017	0.0446	56

* Values calculated as in Tables I and II.

Unsaturated Flow

The movement of bacteria in the partially saturated zones above the ground water table has been of considerable interest to earlier investigators, and it was believed that an effort should be made to determine whether flow under partially saturated conditions was unique.

A column of 0.40-mm sand was arranged for flow at 84 per cent of saturation. The effluent concentration characteristics are shown in Figure 6, which shows a breakthrough similar to that of the coarse sand (Figure 5) and a constant sedimentation removal section. Tension in the liquid phase was 16 to 21 cm, so that pores smaller than 0.15 mm were completely filled, and flow in the larger pores occurred along the pore walls. Calculated values of a_1 and cluster diameters are shown in Tables III together with values for saturated flow.

Table III shows that cluster diameters in the unsaturated column were about one-fifth those in a similar column flowing under saturated conditions, with correspondingly lower removal rates.

Summary and Conclusions

Due to the generally greater sensitivity of the bacteriological techniques, the presence of bacteria cells in percolating water is often detected earlier than the presence of a companion chemical tracer. The first contaminated water to arrive includes the bacteria that have traveled with fastest moving water farthest from the periphery of the stream where the removal potential is greatest. Ultimately, virtually all bacteria are removed by the medium, or their movement is sufficiently retarded so that natural bactericidal forces prevail.

The removal of bacteria from water passing through soil has been described by early investigators as due in part to straining in the contact zones of adjacent grains, and in part to sedimentation in the pores. At least two mechanisms were observed during the experiments described herein. These experiments also demonstrated the interrelation of accumulation on the straining sites and sedimentation, as well as the relative capacities of the removal mechanisms.

The nature of bacterial movement from the soil surface can briefly be described. At first both of the removal mechanisms are operative, and the straining mechanism increases its removal rate as individual bacteria accumulate in the contact zones. When the accumulations become unstable, portions break off as clusters, which are subsequently removed by straining or sedimentation. Accumulation probably occurs principally near the soil surface. When the first clusters break off at the surface an avalanche of bacteria rapidly saturates the straining sites for some distance below, after which the saturated front moves downward more slowly.

The sedimentation removal mechanism has a relatively great saturation capacity. Its removal rate is a function of the flow rate and the size and density of the bacterial cluster. This mechanism also becomes saturated first at the soil surface, and controls the subsequent passage of bacteria.

It is apparent from the foregoing descriptions that the soil surface plays a dominant role in the subsequent travel of bacteria, and operates in a manner to restrict the continued infiltration of bacteria.

Interpretation of the experimental data depends on an estimation of the densities of the individual bacteria or the bacterial clusters. More reliable data are needed on both the physical characteristics of bacteria, and on the clustering phenomenon as related to the liquid velocity.

Acknowledgment

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UNIVERSAL FACTORS IN AEROBIC BIOLOGICAL PURIFICATION *

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Natural stream self-purification is sometimes considered to be essentially different from oxidative waste treatment, such as is applied in an activated sludge plant. The activated sludge plant in a few hours gives a percentage reduction of BOD which requires days in a stream. This is an artifact of operation and design rather than a manifestation of differences in biochemical oxidation rates.

Figure 1 presents schematically the series of transformations which take place in an isolated biological substrate supplied with oxygen continuously and held in the dark after a single feed. The system is assumed to contain a mixed biological population which may be a very small "seed," or a large mass of organisms such as the sludge in an activated sludge system.

A liquid substrate containing food is also present. The food may be dissolved, suspended or in colloidal suspension. Some of the food is designated as common food, and by this is meant food that is readily used by organisms present. Some of the food is designated as exotic food and by this is meant food that is used with difficulty by the organisms present, sometimes after a long lag period in which it is not affected. Sometimes, the biological population may acclimate itself to an exotic food and use the material up rapidly, although some of the exotic foods are attacked slowly even by acclimated organisms (1).

In Figure 1, the ordinate axis represents either oxygen already used or the oxygen required to completely burn up either food or biological cell substance. As an example of how a chemical would be rated, a calculation is made below for ethyl alcohol.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

$$\frac{\text{mol. wt. } 3O_2}{\text{mol. wt. } C_2H_5OH} = \frac{96}{46.07}$$

$$= 2.08 \text{ ppm}$$

The value arrived at is the oxygen equivalent to 1 ppm of ethyl alcohol if the alcohol is completely burned up, either chemically or biochemically. Further calculations of the same kind have been presented by Placak and Ruchhoft (2).

Immediately after the food and the organisms in the substrate come in contact there may be rapid adsorption of some of the food involved. The total material adsorbed ($A + A'$) is likely to be small in most cases and part of the exotic adsorbed chemicals may be released later if the biological solids in the system change in absorbing power or are reduced in amount. After the feed, the amount of biological material present will increase to a maximum as the result of growth and multiplication. Once the maximum amount of biological material is formed, further respiration will result in progressive decrease and destruction of solids. The amount of growth at time T_1 is represented by $B' - B$. After growth reaches its maximum, further aeration results in destruction of biological solids. Upon further aeration (time

* Presented at the 1957 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Chicago, Ill.; June 26–28, 1957.

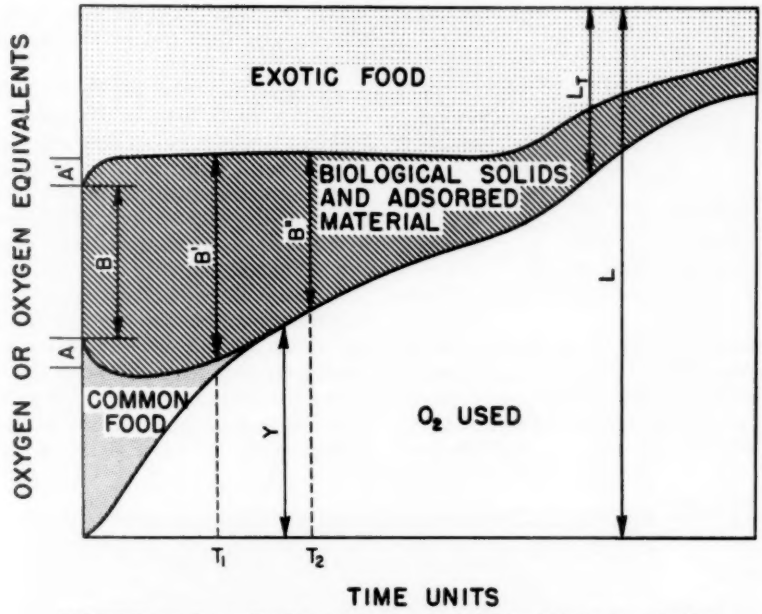

FIGURE 1.—Generalized reaction of a biological substrate to a feeding.

T_2 in Figure 1) the amount of solids present will equal those initially present; continued aeration now causes the amount of biological solids to decrease below their initial level.

As the system ages, the amount of oxygen which has been used (Y) increases. The terms "L" and "L_t" are also shown on Figure 1. If the system studied is a sewage dilution of polluted river water the oxygen usage curve (Y) will trace out the usual curve for carbonaceous BOD.

If the system mentioned previously were an activated sludge mixed liquor and the aeration were stopped at time T_1, then B′ − B would represent the amount of sludge growth and presumable would represent excess sludge requiring disposal.

In both applied aerobic treatment and natural self-purification, complete treatment is represented by the amount of organic material burned up (oxygen used). In an activated sludge plant, purification is accomplished in two ways:

1. By absolute destruction (oxidation).

2. By synthesis and adsorption followed by physical removal of this material along with the sludge.

Biological Treatment Plant

An activated sludge plant (or a trickling filter) accomplishes very fast removal of BOD as compared to natural purification rates. However, in a mixed liquor aeration tank, sewage having 200 ppm of BOD is mixed with returned sludge and the aerobic treatment is carried out in a system which may contain 2,000 ppm of BOD, with most of the BOD present represented by the sludge. If the system is working well, the sludge can and will be separated. However, 200 ppm of BOD has been treated by applying air to 2,000 ppm of BOD and the effluent is purified by oxidation of a load which is ten times as big as the load treated.

In terms of effluent quality, sludge growth may be an important factor of purification. In a summary table

TABLE I.—Division of Feed Chemical Between Oxidation and Synthesis by Activated Sludge

Class	Percentage Oxidized		Percentage Converted to Organized Sludge
	Range	Mean	
Carbohydrates	5 to 25	13	65 to 85
Alcohols	24 to 38	30	52 to 66
Amino acids	22 to 58	42	32 to 68
Organic acids	30 to 80	50	10 to 60

showing the fate of certain groups of chemicals 24 hr after batch feeding to activated sludges, Placak and Ruchhoft (2) presented the data of Table I.

Data of this type have been presented by many investigators such as Weston and Eckenfelder (3) and McKinney *et al.* (4).

The trickling filter offers two points at which BOD may be converted to biological solids and withdrawn from the system. These are the secondary sludge and the retention on the stone. There is an obvious limit to retention of BOD by the stone so that secondary solids are the only point at which BOD may be withdrawn in a trickling filter plant in the form of biological solids or biologically flocculated solids over any long period of time.

In a trickling filter system, the filter slime represents the biological accumulation which is being oxidized in a

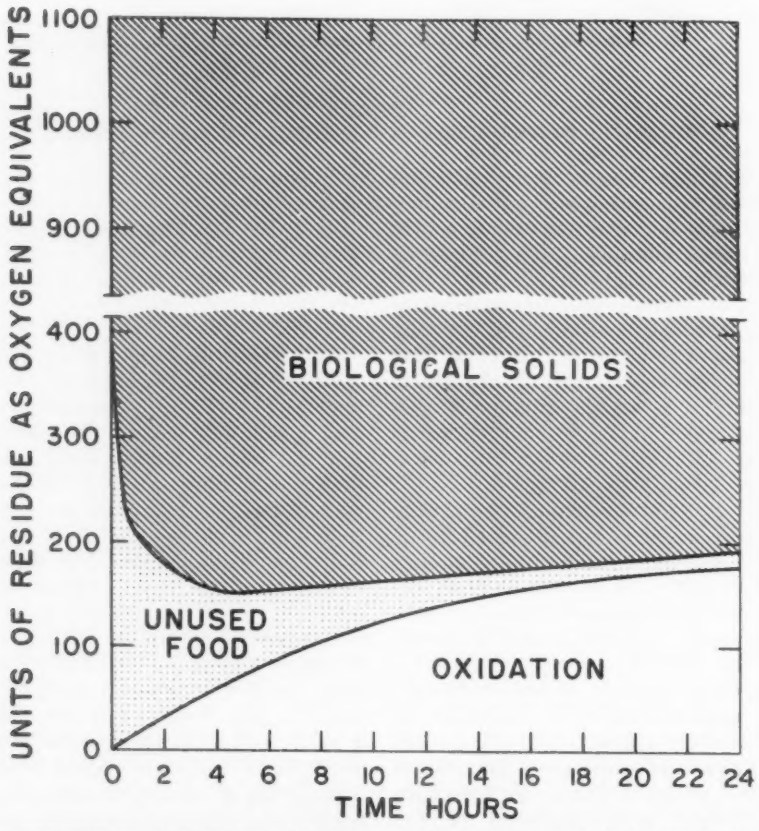

FIGURE 2.—Assimilation of food by a laboratory activated sludge (Ref. 5).

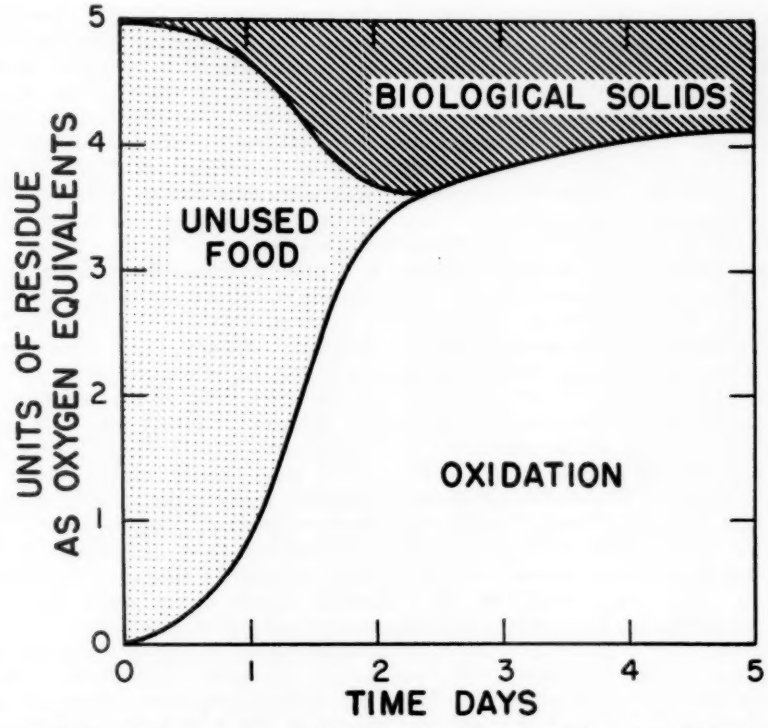

FIGURE 3.—Assimilation of a heavy food dose by a small inoculum (Ref. 1).

manner similar to the activated sludge in an activated sludge system. The slime represents material collected from earlier loads treated and subjected to biological oxidation as long as it is retained on the filter bed.

Figure 2 shows the interaction between 1,000 ppm of activated sludge and a feed with an initial total oxygen demand of 389 ppm, as estimated from data presented by Ruchhoft *et al.* (5). It will be noted that in 24 hr of aeration only about 15 per cent of the total organic load in the system was oxidized. The maximum amount of sludge was present about 5 hr after aeration was started, and during the remaining 19 hr of aeration about 45 ppm of sludge was destroyed by catabolism. Supernatant BOD has been estimated as unused food, although this estimate is high because it includes biologically organized material which did not settle out of the supernatant samples.

Figure 3 presents a similar chart prepared from data presented previously by Ettinger (1) and shows oxidation of a soluble synthetic substrate given a very small initial inoculum of sewage. Examination of Figure 3 shows that more than 50 per cent of the total oxidizable material initially present was burned up biologically during the second day. With the activated sludge system of Figure 2, only about 15 per cent of the oxidizable material was actually oxidized during the 24-hr observation period.

It is quite apparent that activated sludge does not give super oxidation rates as compared to ordinary vigorous oxidations when the total load present in the oxidation system is considered.

Actually, the total organic load in the sludge aeration tank is composed largely of the living organisms making up the sludge, and it is predictable that live sludge is harder to destroy then free food. Oxidation rates shown in Figure 3, for instance, are notably lower when the oxidizable material is present as biological solids.

The effect of a nutritional deficiency on the rate at which biological systems will carry out their purification is well known. If a nutritional deficiency, such as inadequate phosphorous, occurs in an activated sludge plant treating an industrial waste, the rate of purification which the plant can accomplish is limited. Lack of the nutritive element forces the system to re-use the scarce nutrient it contains again and again. New growth must await the release of the scarce nutrient held by the organisms which contain the total supply; such release occurs as the result of predation, lysis, phage induced lysis, etc.

A nutritional deficiency does two things which retard purification:

1. It limits purification rates by limiting the rate of growth of new cell substance.
2. It precludes purification by synthesis of removable cellular material.

In some circumstances, avoiding the need for furnishing nutrients and disposing of excess sludge may warrant use of longer process time, so that limited formation of new biological solids is not to be considered as a universal disadvantage. Protracted aeration, as was discussed earlier, can also control sludge production, even without a nutritional deficiency.

Stream Self-Purification

In discussing both the activated sludge process and the trickling filter, attention has been called to synthesis and sedimentation as an important part of the designed purification system. In the stream, sedimentation is frequently a major factor in freeing a stream of pollutants. Material may settle out directly, be converted to biological substance which settles out, or be converted to biological solids in the form of growth attached to solid objects in the stream, and finally organic pollutants may coalesce with silt and/or biological detritus and be carried to the bottom.

Unlike the sewage disposal plant, the aerobic stream sometimes does not have a rational plan for handling bottom deposits. Ideally, the stream will carry out an aerobic digestion on the bottom with little or no accumulation of deposits. Sometimes a heavily loaded stream will digest bottom deposits anaerobically, giving off an occasional foul smelling, evil looking belch. In many cases however, the material will lie on the bottom in the form of polluted silts or bottom muds which digest slowly until they are washed out with the next river rise. A frequent cause of difficulty to water use is the first water of the stream flush-out. The storage of pollutional material in stream beds is an important factor in improving water quality during low flow periods. If, however, it moves out in massive quantity when the river rises it can cause the least desirable water in the stream to occur at the time of the first flush-out after a long dry spell.

Load Cycles

In the consideration of the hypothetical oxidation model presented, photosynthesis was carefully ruled out by specifying that the system be held in the dark. In many streams photosynthesis leads to greatly supplemented oxygen resources during the day, accompanied by minimal oxygen resources at night. The sewage treatment plant also has a diurnal cycle since most plants receive about two-thirds of their flow and 80 per cent of their organic load during a 12-hr period. The sewage treatment plant

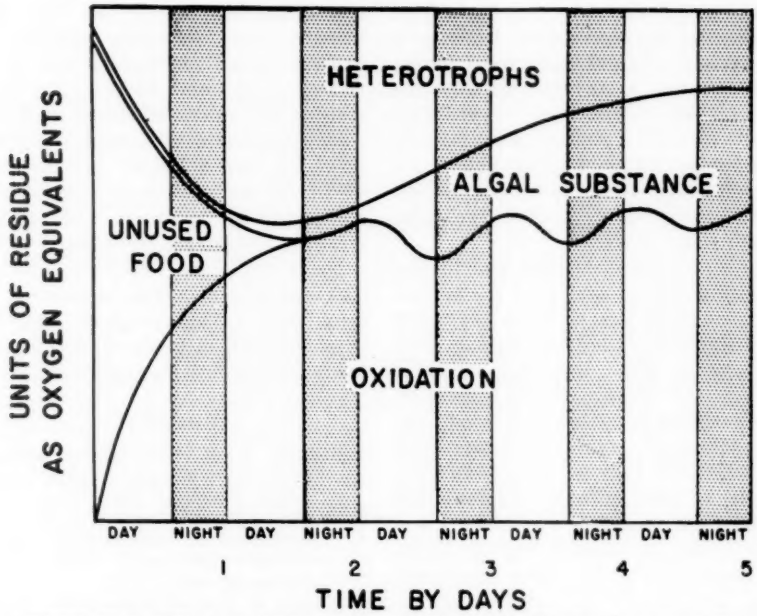

FIGURE 4.—Effect of algal growth on oxidative stabilization in a naturally illuminated system.

then has its excess resources at night and its most critical load during the day.

In some towns, there may be opportunity for advantageous smoothing of loads. For instance, some food processing operations might be arranged to give the greater part of their load to the sewage treatment plant during low load hours. Where sewer rental charges based on flow volume and flow strength are collected, consideration of lower charges for night flows may sometimes be appropriate. Such utility operation is routine with the power companies which give low night rates to the householder who heats his water electrically during the off-load period.

This discussion would be incomplete without an attempt to consider oxidative purification in a cyclically illuminated system. Such a system is considered schematically in Figure 4. Here the system is assumed to contain a mixed biological population that includes species of algae capable of growth in the system. The total biologically organized material is divided into two portions consisting of heterotrophic organisms which require organic food and oxygen for growth, and an algal substance that uses sunlight as the source of energy for growth, and which synthesizes oxidizable organic material from carbon dioxide. Oxygen and carbon dioxide, or a source of carbon dioxide such as bicarbonate, are assumed to be continuously present.

The system presented (Figure 4) initially contains a readily available food supply for heterotrophs, and the system is put under observation at the start of a period of illumination. It is postulated that heterotrophic oxidation will initially predominate in the system. Next, there will be successive waves of algal synthesis related to illumination. This is inferred from the mode of illuminated algal metabolism as described by Odum (6). It is further suggested that the bulk of the daily growth and catabolism wave

caused by photosynthetic cycles will be represented by increase or decrease of the amount of algal substance present. This may not be strictly true since the amount of heterotrophic substance present could be affected also, but the assumption forms a reasonable basis for picturing what happens to the organic content of an aerobic cyclically illuminated system.

Both the algal substance and the organized cellular material of the heterotrophic system are likely to exert but little short time BOD as long as they continue to live. Figure 4 indicates this in the nature of the oxidation curve. Even in an unilluminated sample such as is used on a 5-day BOD test, algal cells may not reveal the magnitude of the organic accumulation which they represent.

In actual illuminated systems there are many variables which have not been included in the over-simplified model offered. These include distribution of illumination as a function of depth, separation of the algal cell material from the substrate, etc. These do not, however, impair the usefulness of the model offered as a key to understanding the behavior of systems in which illumination is important.

Summary

The recurrent pattern of oxidative food usage by microorganisms and oxidative destruction of cell substance in unfed cultures has been described, and it has been noted that these phenomena are essentially similar in natural stream purification and in activated sludge and trickling filter systems. The universal effect of nutritional deficiencies on growth characteristics has been described and the effect of nutritional deficiencies on growth and oxidation analyzed. The sewage treatment plant has been noted to undergo a daily cycle with excess oxidation capacity at night because of reduced load. Algal photosynthesis has been analyzed in terms of its effect on oxidative purification processes.

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CONTINUOUS SAMPLING OF TRICKLING FILTER POPULATIONS

I. PROCEDURES

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The terminology of communities of organisms similar to those occurring on trickling filters has been referred to by Cooke (1) as: "the binding, free-living and grazing or scouring organisms on trickling filter stone form three interdependent communities within the periphyton of the aufwuchs biocoenose of the benthos, and they include both true benthic and facultative benthic-planktonic organisms which may be sessile or sessile-attached to the substratum. Those that are sessile-attached are true lithophytes, lithozoons or lithobionts, depending on the type of organism under consideration." In the same paper various methods were described for sampling such populations by exposing artificial bare areas for colonization.

Literature Review

Information on trickling filter populations is limited. Stanbridge (2)(3), in an extensive series of literature reviews on the development of biological filtration, has discussed the information available to him regarding the development of trickling filter films. These films include such organisms as algae, fungi, bacteria, protozoa, and metazoa. Cooke (4)(5)(6) has surveyed the reports dealing with fungi in such habitats. In his thesis on the fungi in two domestic sewage treatment plants, Becker (7) also reviewed much of the literature in this field. Becker and Shaw (8) observed fungi in progressively decreasing numbers in the effluents of successive processes in some sewage treatment plants. Filter bed slimes were sampled once; from the results of microscopic observations and platings it appeared unnecessary to sample this habitat further. Feldman (9) has described several fungi in experimental filters.

Tomlinson (10) and Hawkes (11) indicated that rate and periodicity of dosage have profound effects on filter populations. Less slime was produced on filters with long intervals between dosing than on those with short intervals.

In 1953, Heukelekian and Crosby (12) were interested in the inhibition of various microorganisms forming slimes and causing deterioration of pipes, walls, and other structures for the conduction of waters, sewages, and industrial wastes. They found that slime accumulations were subject to retardation by sloughing; that the coatings studied were ineffective on either short- or long-term bases; that an initial retardation of growth was counteracted with time; and that a complete inhibitor in the concrete or the coatings was needed to prevent development of such growths.

In 1955 and 1956 Heukelekian and Crosby (13)(14)(15) made a series of tests to determine the rate of slime accumulation on various surfaces under a variety of conditions in sewage-carrying channels and in the laboratory. In the laboratory, 3- by 1-in. glass slides were exposed to screened and settled sewage in submerged air-lift recirculation, alternate dipping,

submerged dipping, and submerged static conditions. In addition, similar sized surfaces of transite and glazed tile were exposed. These materials were also used in studying the attachment of organisms in channels carrying sewage by exposing some 4-in. squares of the materials clipped to frames which were submerged for varying periods of time. The plates were submerged in a vertical plane parallel to the flow in the channel.

It was observed that the nature and texture of a surface had no ultimate effect on the amount of slime growth, but initially smooth surfaces were less effective than rough. More growth occurred under aerobic than anaerobic conditions. The nature and concentration of food materials affected the production of slime: when food was reduced by artificial dilution or by removal and oxidation, growth increased; growth also increased when glucose and peptone were added. The velocity of the current increased the eventual amount of attached growth, but inhibited it during the primary period. The slime growth was cyclic: there was an initial lag, a rapid accumulation, a sudden decrease from sloughing followed by rapid accumulation, and more sloughing.

Moisture, ash, and nitrogen content of accumulated slimes corresponded to those of solids collected by settling raw sewage. It was considered that the 1 per cent nitrogen obtained from the growth was too low to be accounted for by cell substance alone, and, therefore, sewage solids were probably imbedded in the slimes. In considering the biological characteristics of the slimes, only bacteria and protozoans were emphasized and the occurrence of these was compared as to methods of slide exposure and the surfaces used. Flagellates were the most abundant organisms present in the anaerobic exposures whereas a wide variety of organisms was present under aerobic conditions. Protozoans were dominant in all types of submergence. This type of analysis indicated that only organisms recognizable to the observer through the microscope were considered important.

Various devices have been developed since 1915 for sampling selected portions of complex populations. In a technique described by Tomlinson (16), five glass microscope slides 1 by 3½ in. were mounted side by side in photographic frames. These frames were laid on the bed of a stream and held fast by anchored brass chains. The results from four slides were examined quantitatively for accumulated weight; the fifth was used for identification and enumeration of organisms. Using this method, algae were studied in relation to stream pollution. Fourteen-day exposures were found to be inadequate for optimum results, but this technique was later modified for use in the study of populations on trickling filter beds. Four 3- by 1-in. microscope slides were mounted in photographic film holders, exposed on the surface of trickling filters, and the amount of growth was weighed periodically. The weights were found to be comparable to those of growth materials on similar areas of filter stones. The growth was found to vary quantitatively with 3- to 4-day and 7- to 14-day alternations in filter operation periods.

In studying the productivity of Sodom Lake, Mich., Newcombe (17) exposed three series of slides during late summer and early fall to determine the "attachment material" "seeded on." One series of slides was used for determining the loss of weight on ignition, a second series for chemical studies, and a third series for a quantitative study of materials after suspending them in glycerin. The mean growth weights of the upper surface, the lower surface, and the combined surfaces of six slides were compared. It was found that the horizontal position gave best growths of attachment materials. From the results of this study, a formula was developed

for "seeding-on" based on "compound interest at a constant rate."

Other techniques which have been developed for studies of this type rely on less critical quantitative or qualitative analyses. These consist of direct observation of natural materials attached to the slides, or of prepared slides. Using natural materials, specific groups of organisms only are studied, ignoring any other types which may appear; with prepared slides, only specific groups for which special preparations have been made can be studied. Such exposures are also used to determine the efficacy of surface treatments to determine whether or not groups of organisms can survive under specified conditions. The basic technique for the present study was modified from one described by Tomlinson (16).

Sample Collection

In a preliminary set of exposures, four glass microscope slides, 3 by 1 in., were fixed in place in stainless steel photographic film holders with rustproof nichrome wire in such a way that a continuous surface was provided. Fifteen holders were placed on a standard trickling filter, and fifteen on a high-rate trickling filter. Pairs, one from each type of filter, were removed after 24 hr, 48 hr, four days, and one week, then at weekly or biweekly intervals until all were removed. The three-month observations proved inadequate because questions arose which could not be answered satisfactorily. The intervals between bi-weekly removals were too long to explain developing fluctuations.

This report is based on observations of exposed glass microscope slides fixed to pieces of ¼-in. mesh galvanized hardware cloth 4 by 6 in. in size. The slides were mounted separately on the hardware cloth with 25- or 30-lb nylon fishing line. Each slide was numbered, oven dried, and weighed before mounting. Each frame was identified by a numbered copper tag. Before exposure the completed frames were oven-dried and weighed. Sixty frames were placed in a row on a high-rate and a standard trickling filter on November 22, 1954. No attempt was made to place all the frames in the same position. Some slanted in one direction, some in another, a few were nearly horizontal, none were vertical, and most were at an angle of less than 30° from the horizontal. One frame from each filter was removed after 24 hr, 48 hr, four days, and one week, and on each Monday thereafter. The last set was collected on December 26, 1955.

Sample Transportation

For purposes of shipping with minimum disturbance to the growth on the slides, a special wooden container was devised, with inside dimensions designed to accommodate the two frames after they had been wrapped separately in lead foil. The wrapped frames were then padded with cardboard to prevent movement within the box. Transportation in this way was satisfactory. The growth, even after three or four days in transit, was still moist and typical; no sign of a septic condition appeared so that even *Psychoda* adults and larvae survived the journey in good condition. Frames transported to the laboratory by car were carried in a wire basket, protected from excess evaporation by wrapping the basket with a huck towel.

Laboratory Techniques

Upon receipt at the laboratory, the frames were unwrapped and allowed to dry under room conditions for about 24 hr. This was sufficient time for the slides to become "air dry" as evidenced by a tendency of the material to flake. After drying, the frames were weighed on a torsion balance. They were then dismantled by cutting the string and removing each slide carefully to a separate Petri dish. Each slide was then weighed. Excess

materials on the frame were removed to separate petri dishes and retained. The slides and excess materials were then stored in a refrigerator for further study.

Growth Removal

To enumerate and identify the populations of organisms on the slides, several techniques were tried. At first the fungi formed the focal point of this study but later, as algae increased in visible quantity, these also were quantitated. The numbers of bacteria, protozoans, and metazoans were not estimated but these organisms could be observed in any fresh mounts made.

During the early stages of exposure, the slides were immersed in plates of dextrose phytone salts rose-bengal agar. Colonies developed around the periphery of the slides and over the exposed surfaces. Two slides from each frame were plated top side up, and two bottom side up, in order to get an estimate of the fungi occurring on all surfaces. As visible growth increased, after the first two or three weeks of exposure, various ways of removing the growth to determine its amount and type were explored.

At first, the dry slide was scraped with a scalpel. In this way much information about types of fungi and numbers of colonies was obtained, but on plating the slides it was found that much material remained, since about as many colonies remained on the slide as were removed. Finally, the slides were remoistened and the growth and other materials removed with a rubber policeman. When this method was used to remove wet material, 5 to 15 per cent of the organisms were left on the slide, as indicated by occasional slide platings. This percentage of residue was approximately proportional to the amount of material that had accumulated on the slide.

To recover the dried growth in as short time as possible, the slides were transferred from the refrigerator to a petri dish and covered with 20 ml of distilled water. The following morning the materials were removed from each slide with a rubber policeman. The materials from the top of the slide, as it was exposed, were kept separate from the bottom materials, as well as from those excess materials associated with the slide but accumulated on the frame and enmeshed in the nylon string. Each of these three groups of materials was considered a "unit." No attempt was made to interpret "unit" in terms of weight of dry matter present.

Plating

Depending on the duration of slide exposure, the top materials constituted 5 to 15 per cent of the total weight of growth per slide and the excess materials probably amounted to at least 200 per cent of the weight of material on a single slide. Each unit of material was added to 80 ml of distilled water in an Erlenmeyer flask. Materials from the top of the slide were then agitated in a Waring Blendor at high speed for 10 sec, bottom-of-the-slide materials were blended for 20 sec, and excess materials for 30 sec. These times gave relatively uniform suspensions for plating.

Dilutions for plating were made so that colonies appearing on the agar in petri dishes would not be difficult to count, identify, or pick for future study. Depending on the amount of material present, flask dilutions of 1:1,000, 1:10,000 or 1:50,000 were used. Later, when algae became evident on the slides, 20 ml of suspensions were removed from each flask at the 1:10 dilution level for further study and algal cell or cell-clump counts were made.

Each type of sample was inoculated in four replicate plates of dextrose phytone salts rose-bengal aureomycin agar as described by Cooke (5). This medium is now available in prepared dry form to which antibiotics only need to be added.

Incubation

The samples were incubated in conditions of room temperature and light for seven days and then counted and inventoried. With few exceptions identification of colonies was made directly from the plates. A few colonies of special interest were picked for systematic study at later dates. Most colonies not readily identifiable were lumped into general categories so that *Moniliaceae* spp., *Dematiaceae* spp., *Penicillium* spp., and "White Yeasts" were groups in which more than one species were represented. With the possible exception of the White Yeasts, the individual species forming these categories may be of little importance because of their small numbers.

Counting

The numbers of algae were determined by counting a portion of the sample after it had been fragmented by a Waring Blendor. Samples from the tops or bottoms of the four slides in any one series were lumped together and counted in a Palmer nannoplankton slide (18) at a magnification of 430 diameters. The number of fields counted ranged from 15 to 100 depending on the abundance of algae in

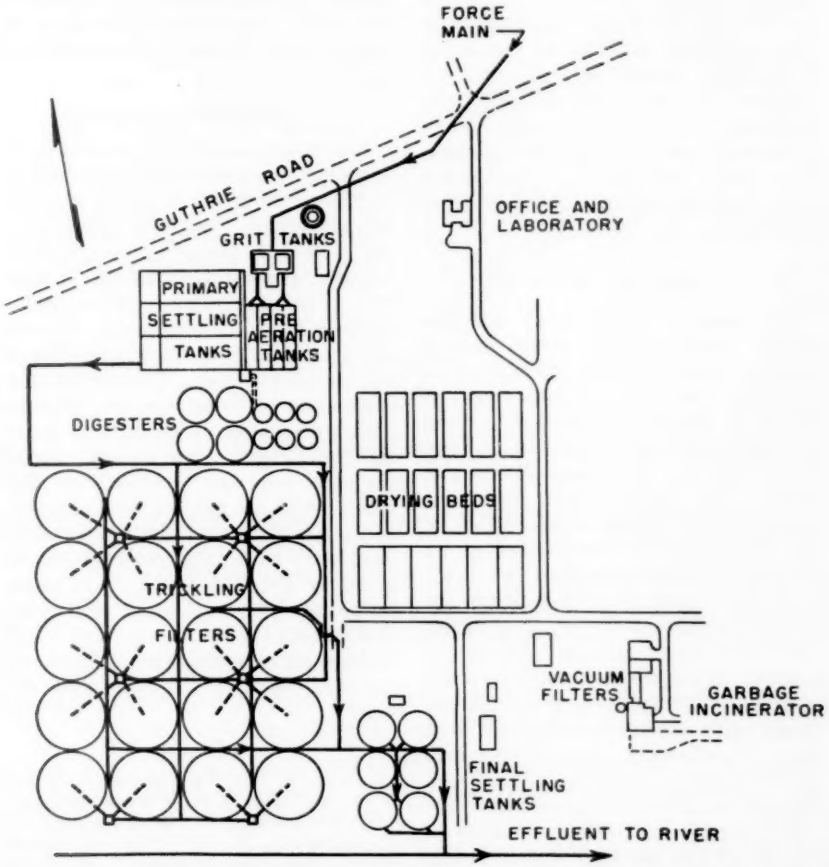

FIGURE 1.—Flow diagram, Dayton, Ohio, sewage treatment plant.

the sample. The entire slide was then scanned to enumerate species not detected in the field count.

The first visible evidence of algal growth appeared on the slides on January 3, 1955. At that time the bottom surfaces of the slides from the high-rate filter appeared green. The first slides examined quantitatively for algae were those returned on February 21, and the counting was continued to the end of the exposure period. Algae were counted as single cells in the case of unicellular species, or as clumps of cells in the case of colonial unicellular species and of those species whose thalli were formed of simple or branched chains of cells. Because the growth mat was highly fragmented, it was sometimes difficult to determine the number of cells in a filament and whether or not the filament was branched. It was not practical to equate the cells of blue-green algae, green algae, and diatoms to produce a more accurate quantitative picture of the algae on the filters.

Sampling Area

The location under study was the sewage treatment plant of the City of Dayton, Ohio. During the period of sampling, the flow pattern was as shown in Figure 1. Sewage entered the plant through a force main and large detritus was removed in grit tanks. The sewage was then sent through pre-aeration tanks where it was aerated briefly before flowing into the primary settling tanks. The liquid from these tanks flowed directly to the dosing chambers of the trickling filters. The solids were processed by heated primary and secondary digesters, and dewatered on drying beds or vacuum filters. The air-dried sludge was heat treated, pulverized, sacked, and sold as "Or-So-Con," an organic soil conditioner or fertilizer supplement.

The filter-dosing chambers were so arranged that the high-rate trickling filters received a steady capacity flow. The standard trickling filters received the surplus settled sewage only, and were therefore idle during part of each day. Effluents from both types of filters were sent to common settling tanks from which the liquids were discharged to the Great Miami River and the solids returned to the grit tanks. Since the effluents were not measured, tested, or treated separately, no information is available concerning the degree of efficacy of either type of filter treatment.

An average of 41.2 mgd of sewage was treated by the plant during the course of the study. In general, heavy flows occurred in the summer; the month of July showed an average of 49.8 mgd. Low flows occurred in the winter with December averaging 36.3 mgd.

Acknowledgments

This study could not have been undertaken or completed without the help and encouragement of personnel at the Dayton sewage treatment plant, especially of L. T. Hagerty, plant superintendent, and his assistant, R. H. Calihan. Various employees also served as occasion arose. Assistance in planning the study was given by Eugene Harris and Graham Walton. George Matsuura assisted in technical details concerned with preparation, plating, and counting the fungi. Alan Hirsch counted the algal cells and identified the algal species with the help of those acknowledged in the text on algal populations. Assistance with statistical analyses was given by Kenneth Busch. The manuscript has been read by C. M. Palmer, G. Walton, W. W. Towne, and P. W. Kabler, all of whom gave valuable aid in clarification of the ideas here presented.

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MEETINGS OF INTEREST

1958

Jan. 27–31 **Missouri Water and Sewage Works Training Courses,** University of Missouri, Columbia, Mo. Professor L. T. Murphy, College of Engineering, University of Missouri, Columbia, Mo.

Feb. 26–28 **American Society of Civil Engineers,** Sherman Hotel, Chicago, Ill. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.

Mar 17–21 **Fourth Nuclear Engineering and Science Conference,** International Amphitheatre, Chicago, Ill. (See page 45.)

Apr. 18 **Annual Pennsylvania Clean Streams Conference,** Penn-Harris Hotel, Harrisburg, Pa. Pennsylvania State Chamber of Commerce, Harrisburg, Pa.

Apr. 20–25 **American Water Works Association,** Dallas, Texas. Harry E. Jordan, Secretary, AWWA, 2 Park Ave., New York 16, N. Y.

STUDIES ON SLUDGE DIGESTION AND METHANE FERMENTATION

I. SLUDGE DIGESTION AT INCREASED SOLIDS CONCENTRATIONS

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Sludge digesters are usually operated at solids concentrations of from 3 to 10 per cent. If it were possible to operate at solids concentrations of from 6 to 20 per cent, this would mean a reduction in size of the digesters by one-half. The effect of increased solids concentrations on sludge digestion is, therefore, a problem of practical interest.

Method of Study

The experiments were carried on in cylindrical laboratory digesters made from lucite as shown in Figure 1 (A). The digesters had a volume of 4 l. In most cases they were filled with 1,000 or 2,000 ml of active digesting sludge. The material in the unit was continuously agitated by a stirring mechanism (B) at 0.5 rpm. The stirring speed was later increased to 4 rpm. To insure gas tightness the stirring rods passed through a ½-in. length of ¼-in. tygon tubing (C) set in the plastic cover as a sleeve bearing. The units were placed in a water bath (D) maintained at a temperature of 32° ± 1° C. A thin film of machine oil on top of the water prevented evaporation.

The fermentation unit had two openings. One opening was connected to the upper end of a 2.5-l gas collecting cylinder equipped with a leveling bulb; the other opening was fitted with a two-hole No. 8 rubber stopper. Feeding of materials such as dried raw or digested sludge was accomplished by removing the No. 8 rubber stopper and inserting a powder funnel. Acids were fed by inserting the spout of burette (E) through one of the holes of the rubber stopper. The other hole was normally closed by a "00" size rubber stopper and was used to withdraw samples by means of a glass tube. Gas tightness of the units was checked by applying a head of approximately 20 in. of water overnight while the stirring mechanism was running. Gas losses were normally not more than 5 to 10 ml under these conditions. All gas readings were corrected to a temperature of 25° C and 760 mm of mercury by using a special slide rule as described by Snell (1). Occasional gas analyses were made. The gas had a normal composition as shown by the following two examples:

	Analysis (%)	
Gas	Unit No. 7	Unit No. 11
CO_2	27.0	32.0
O_2	1.0	1.0
H_2	2.2	—
N_2	2.4	—
CH_4	67.4	67.0

Subsequent gas checks were made regularly by burning samples from the gas-collecting cylinders. Except for the initial stages, all gas samples burned with a pale blue methane flame.

Determinations of dry solids, ash, or volatile matter and volatile acids were made according to "Standard Methods" (2). All gas rates were expressed as milliliters of gas per day per liter of active digester volume.

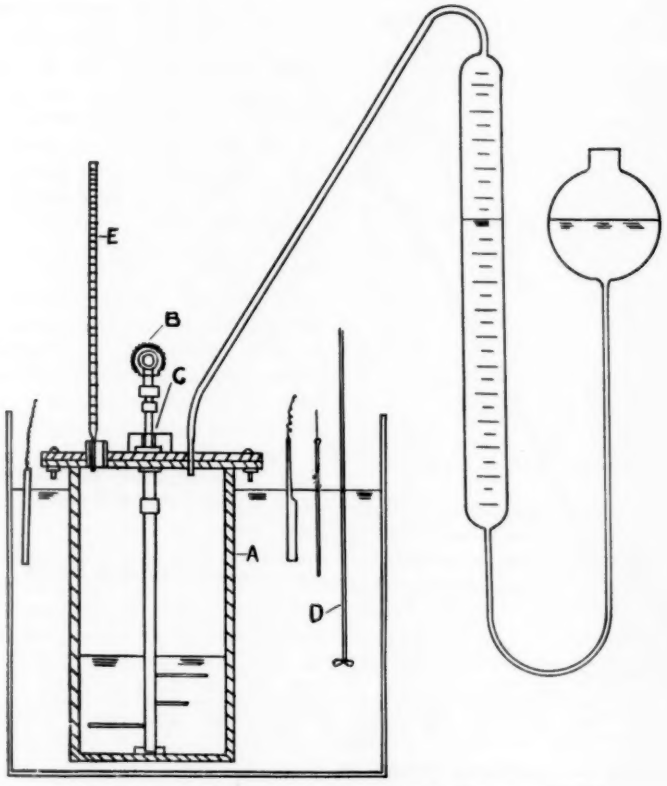

FIGURE 1.—Schematic diagram of fermentation apparatus.

The active digesting sludge used as seeding material was taken directly from the primary digester of the East Lansing, Mich., sewage treatment plant. Raw sludge was taken from the primary settling tanks; centrifuged, air-dried, and ground in a laboratory mill. For the studies involving a gradual increase in solids concentration, dry digested sludge was used. The material was taken from the sludge drying beds, freed of sand, and ground in a laboratory mill.

When dry materials were added to the digesters or samples were taken, the leveling bulb was set even with the brine level in the gas-collecting cylinder, so that no head existed and thus the entrance of air into the unit was kept at a minimum. The dry solids determinations showed a considerable degree of variation because stirring was at a slow rate and did not prevent the formation of layers of lighter and heavier solids in the digesters.

Experiments

For the first series of experiments, seven units were started with raw sludge preparations ranging from 10 to 60 per cent dry solids. Each digester contained 119 g of air-dried raw sludge, 104 g of active digesting sludge from the East Lansing digester as seeding material, plus various amounts of distilled water to establish 10, 20, 30, 40, 50 and 60 per cent dry solids. The seventh unit contained 2,000 ml of the seeding material as a control. The

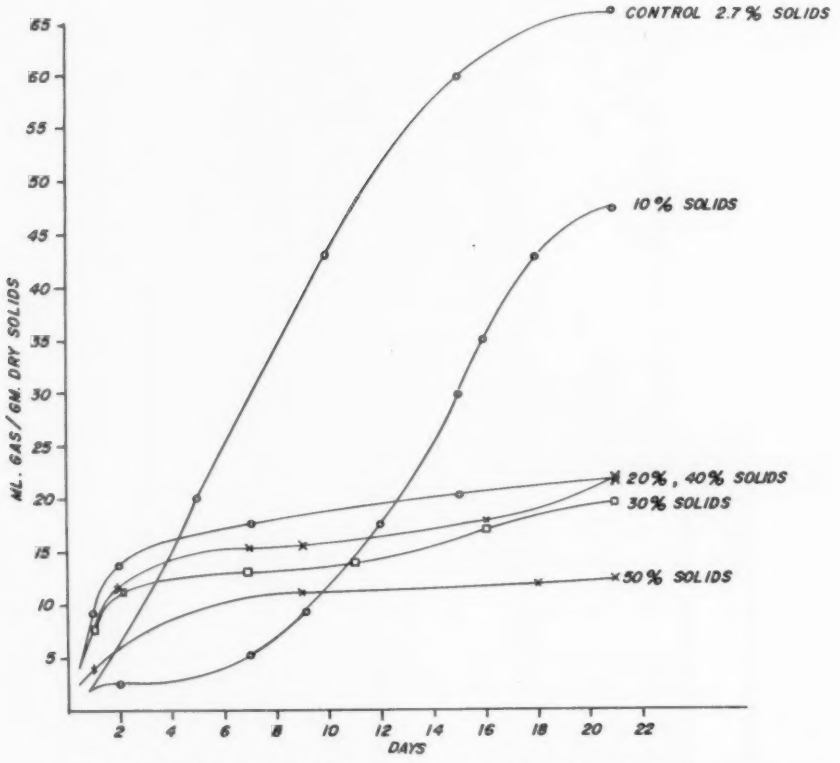

FIGURE 2.—Relationship between gas production and solids concentration.

air-dried ground raw sludge analyzed as follows:

Item	Per Cent
Moisture	4.7
Volatile matter	71.3
Ash	28.7

The seeding material analyzed as:

Item	Per Cent
Solids	2.7
Volatile matter	49.5
Ash	50.5

Checks were made on dry solids, gas production, pH, and volatile acids concentration.

Figure 2 gives the results of these experiments where the curves show the gas production in milliliters per gram of dry solids for the units containing 10, 20, 30, 40, and 50 per cent dry solids. Only at a concentration of 10 per cent solids was there an appreciable amount of gas produced, but even then gas production stayed below the value of 66 ml of gas per gram of dry solids for the control. The gas rate dropped to practically zero in all the other units after a period of six days.

A repetition of the same experiment brought similar results. The accumulated data are shown in Figure 3. The total gas produced per gram of dry solids after 51 days was plotted against the concentration of dry solids. The curve shows that with increasing solids concentration, the gas production decreases rapidly.

The pH data pertaining to these experiments are shown in Figure 4. They indicate that with increasing solids concentration, a slight drop in pH occurred; however, in only one

case, 54 per cent solids, did the pH reach a value of less than six.

Results of the volatile acids determinations are plotted in Figure 5. The data show that all units except the control were characterized by an intense production of volatile acids. The rate and the degree of this volatile acids production was remarkable. After a period of 10 days, all units except two contained from 5,000 to 10,000 ppm of volatile acids. The acid production continued for several months and reached values of 54,000 ppm in the unit containing 51 per cent solids. It appears that the production of volatile acids was the principal process taking place in these sludge mixtures.

According to Buswell (3) there exists a critical volatile acids concentration level of 2,000 to 3,000 ppm, above which the methane gas production is greatly impeded. It has become general practice to control digesters for volatile acids increase beyond this level. If Buswell's observation is assumed to be correct, it can be concluded that the failure of all the units containing high solids concentrations

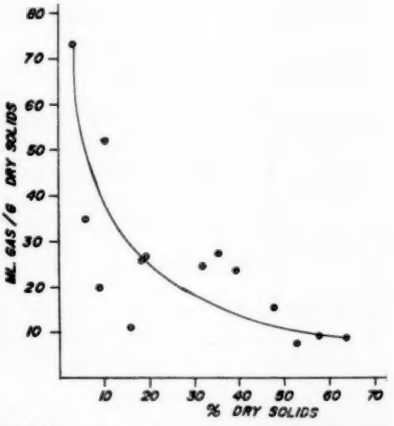

FIGURE 3.—Gas and solids relationship after 51 days of gas production.

to produce methane was due to an excessive formation of volatile acids. A successful methane fermentation, or digestion of sludge, at dry solids concentrations greater than 10 per cent would be possible only if this excessive volatile acids production could be avoided.

One way to accomplish this seemed to be the gradual controlled addition of dry solids to a functioning digester

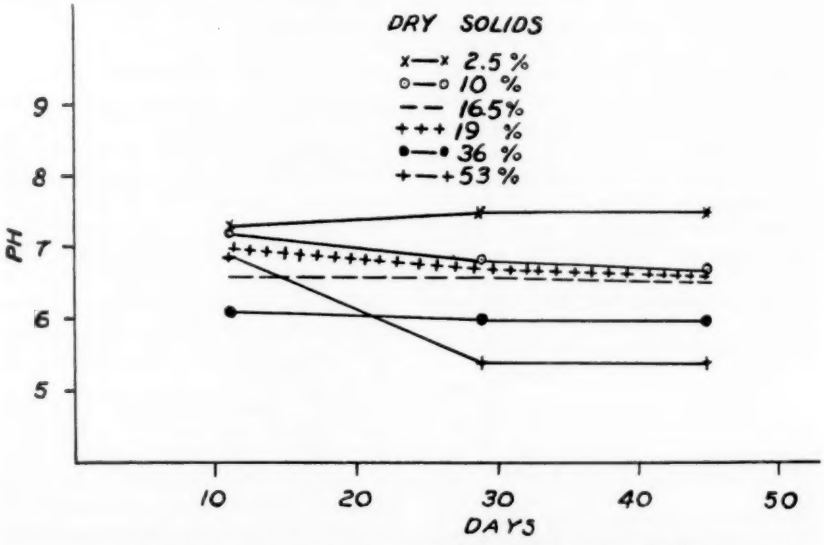

FIGURE 4.—Relationship between pH and solids concentration.

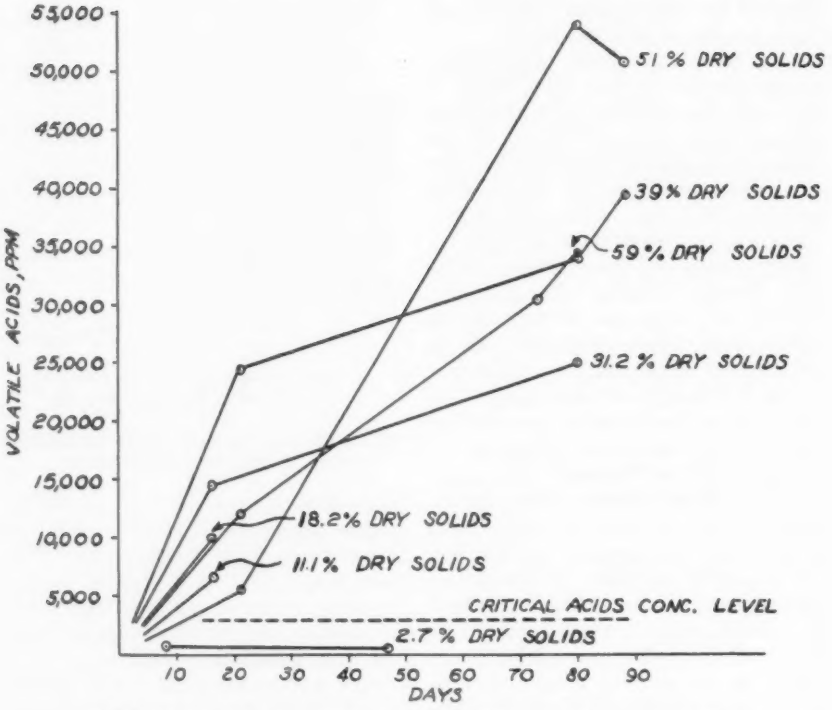

FIGURE 5.—Volatile acids formation at different solids concentrations.

unit. To step up the solids concentration in larger increments, air-dried digested sludge from the East Lansing sewage treatment plant was used. Several checks showed that 40 to 45 ml of gas could still be produced per gram of dry solids added. On the other hand, it was obvious that by feeding approximately 100 g of dry digested sludge to a laboratory unit, only a small amount of digestible material was added, thus reducing the danger of overloading.

TABLE I.—Analytical Data for Experimental Digester Units

Item	Digesters		
	No. 1	No. 2	No. 3
Dry solids (%)	7.9	16.5	49.75
Volatile matter (%)	43.0	38.7	35.3
Ash (%)	57.0	61.3	64.7
pH	7.2	6.7	7.3
Volatile acids (ppm)	860	620	1,208

Gas Production

Use of Dry Digested Sludge

Initially three units were used for investigating (a) the amount of gas produced, (b) the rate of gas production per day, and (c) the volatile acids formation from air-dried sludge. Unit No. 1 contained 1,000 ml of active digesting sludge from the East Lansing digester and served as a control. The analytical data for this material are given in Table I.

Active digesting sludge from the same sample was used for units No. 2 and No. 3. Unit No. 2 was prepared by mixing 100 g of ground air-dried digested sludge (94.6 g of absolute dry solids) with the active digesting sludge so that a volume of 1,000 ml was ob-

tained. The composition of the dry digested sludge was: 5.4 per cent moisture, 35.9 per cent volatile matter, 64.1 per cent ash. The analytical data for the mixture are given in Table I.

Unit No. 3 also contained 1,000 ml of material; however, in this unit 500 g of air-dried digested sludge was mixed with active digesting sludge so that a solids concentration of about 50 per cent was reached. The analytical data are given in Table I.

The results of these experiments are presented in Figures 6, 7, 8, 9 and 10. Unit No. 1 produced 3,350 ml of gas in 34 days, corresponding to 42.4 ml of gas per gram of dry solids, or 98.5 ml of gas per gram of volatile matter. Unit No. 2 produced 7,400 ml of gas in 34 days, corresponding to 44.8 ml of gas per gram of dry solids, and 118.0 ml of gas per gram of volatile matter. The difference between the total gas produced in units No. 1 and No. 2 (4,050 ml of gas) could be attributed to the added 94.6 g of dry digested solids, which amounted to 42.8 ml of gas per gram of dry solids and 119.0 ml of gas per gram of volatile matter. According to data by Imhoff (4), this represented 13.4 per cent and 15.6 per cent of the average gas production from raw sludge solids and shows that the air-dried digested sludge used for these and the other experiments contained only a relatively small amount of fermentable material.

Application of the Monomolecular Equation

The gas production followed a regular pattern and the cumulative gas curve resembled a monomolecular reaction curve as shown in Figure 6. Therefore, an attempt was made to apply the monomolecular equations to the data. The application is based on the assumption that the reaction velocity k is a function of the concentration of the organic matter remaining to be decomposed:

$$\frac{dy}{dt} = k(A - y) \ldots\ldots\ldots (1)$$

In which A = total amount of gas generated during digestion; y = amount of gas produced in time t; k = reaction constant, t = time in days. In integrated form the equation becomes:

$$y = A(1 - e^{-kt} \ldots\ldots\ldots (2a)$$

To determine k from the experimental data, k was set equal to $1/t$ in Eq. 2. It follows then:

$$y = A(1 - e^{-1}) = 0.63A \ldots (3)$$

The time t found for 63 per cent of the total amount of gas produced would then be equal to $1/k$, where t for $0.63A$ = 2,110 ml of gas in curve A (Figure 6) was found to be seven days, and therefore $k = 1/7 = 0.14$. The corresponding values for curve B (Figure

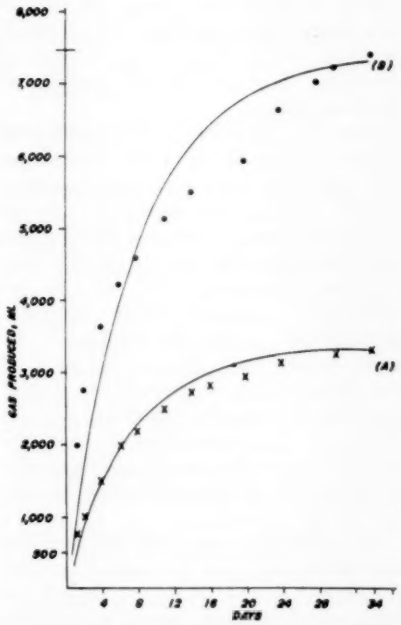

FIGURE 6.—Comparison between experimental and theoretical gas production. Unit No. 1 (A). Unit No. 2 (B).

6) were $0.63A = 4{,}660$ ml of gas at $t = 8$ days, and $k = \frac{1}{8} = 0.125$.

The equations used for plotting the theoretical cumulative gas production were: $y = 3{,}350(1 - e^{-0.14t})$ for curve A, and $y = 7{,}400(1 - e^{-0.128t})$ for curve B.

Figure 6 shows that the experimental data fit the theoretical curve closely for unit No. 1, whereas, in the case of unit No. 2, there is a considerable lag for the period from the 10th to the 28th day. These discrepancies may be due to the loss of gas when samples were taken. In general the equation adequately describes the digestion.

The reaction velocity is indicated by the characteristic constant k. The smaller the constant the slower the reaction rate. Normally, in batch experiments where the amount of seeding material is small compared to the raw solids to be digested, an S-shaped gas production curve is obtained. After an initial lag phase, the rate of gas production increases until about one-half of the final volume of gas is formed. The rate of gas production then decreases.

For the mathematical formulation of this S-shaped curve, Fair and Moore (5) used the autocatalytical equation which contains two constants. As an alternative, they separated the S-curve into two parts; the first followed an exponential equation while the second followed a monomolecular equation. Apparently, under the conditions described here, only the second part of the S-curve applied, since the initial lag and the exponential phase did not develop. The reason being that the amount of seeding material was large as compared to the amount of digestible matter added.

The reaction constant found by Fair and Moore (5) for the second part of the curve was $k_2 = 0.0732$, based on $\log_{.10}$, or $k = 0.168$, based on natural log., which is comparable to the value of 0.14 for k as obtained in this study. The reaction rate can be expressed in a more comprehensive way by using tx, the half-time value, instead of k. The value tx denotes the time needed to decompose one-half of the original digestible material present. In Eq. 2a

$y = \frac{A}{2}$, so that

$$\frac{A}{2} = A(1 - e^{-ktx}) \ldots\ldots (2b)$$

It follows that

$$tx = \frac{1}{k} ln2 \ldots\ldots\ldots (4)$$

For unit No. 1 $tx = \frac{0.693}{0.14} = 4.95$ days,

and for unit No. 2 $tx = \frac{0.693}{0.125} = 5.5$ days.

According to these data it took about five days to digest one-half of the fermentable material present in unit No. 1 and 5.5 days to do the same in unit No. 2.

In Figures 7 and 8 the experimental gas rates, in milliliters of gas produced per day, are compared to the theoretical curves for units Nos. 1 and 2. The formula for the gas rate was derived as follows: substituting $A(1 - e^{-kt})$ for y in Eq. 1 then

$$\frac{dy}{dt} = k(A - e^{-kt}) \ldots\ldots (5)$$

The experimental data of unit No. 1 fit the theoretical curve better than those of unit No. 2. Generally the gas rate seemed to be a sensitive part of the system. As will be seen later, gas rates changed rapidly with changing conditions in the units. Both curves are generally in agreement with the assumption that in batch operation the gas production decreases from day to day in an amount proportional to the concentration of digestible matter remaining.

The data on volatile acids concentration for units No. 1 and No. 2 are

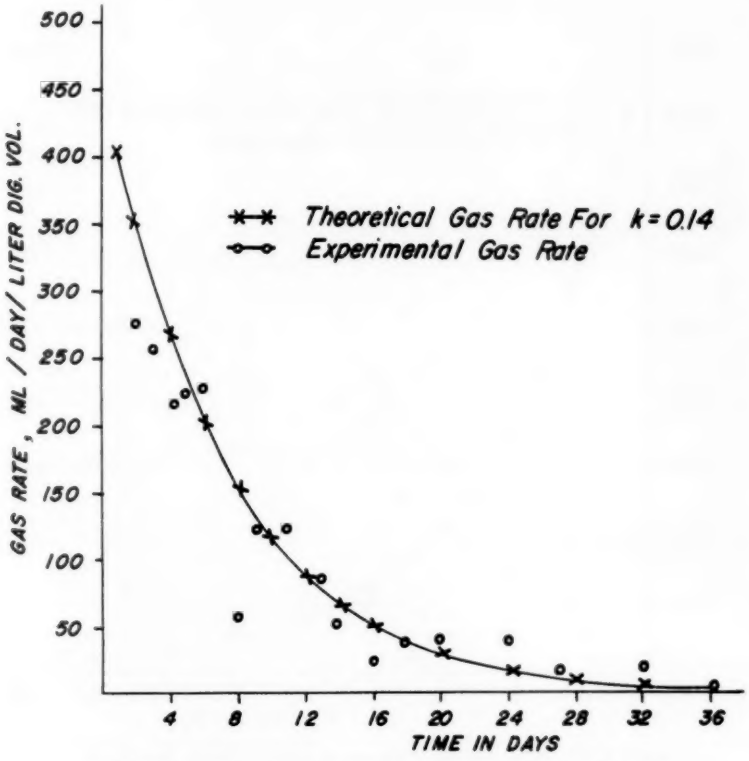

FIGURE 7.—Gas rate per 1,000 ml of active volume, unit No. 1.

plotted in Figure 9. In unit No. 1, low values ranging from 800 ppm to 300 ppm were recorded during the course of digestion. In unit No. 2, which received an initial feeding of 100 g of air-dried digested solids, a characteristic increase in the volatile acids concentration took place. A concentration of 1,740 ppm was reached after a seven-day period following which the concentration decreased steadily.

Unit No. 3 with 49.75 per cent dry solids, obtained by a heavy feeding of 500 g of air-dried digested solids, showed a completely different behavior. The data on gas rates, pH, and volatile acids concentration are plotted in Figure 10. The gas rate decreased rapidly from 812 ml on the first day to 0 ml on the sixth day. At the same time the volatile acids concentration rose sharply from 1,208 ppm to 47,100 ppm. The pH changed only slightly from 7.3 to 6.9. Again, as in the previously reported experiments using raw sludge, the results indicated that the addition of excessive amounts of digestible material favored the production of volatile acids. The formation of organic acids apparently became the dominating process. If, as appears, volatile acids concentrations exceeding 3,000 ppm are harmful to methane bacteria, then this might serve to explain the complete cessation of methane production. Certainly the changes in pH were not sufficient to cause this complete breakdown of methane fermentation.

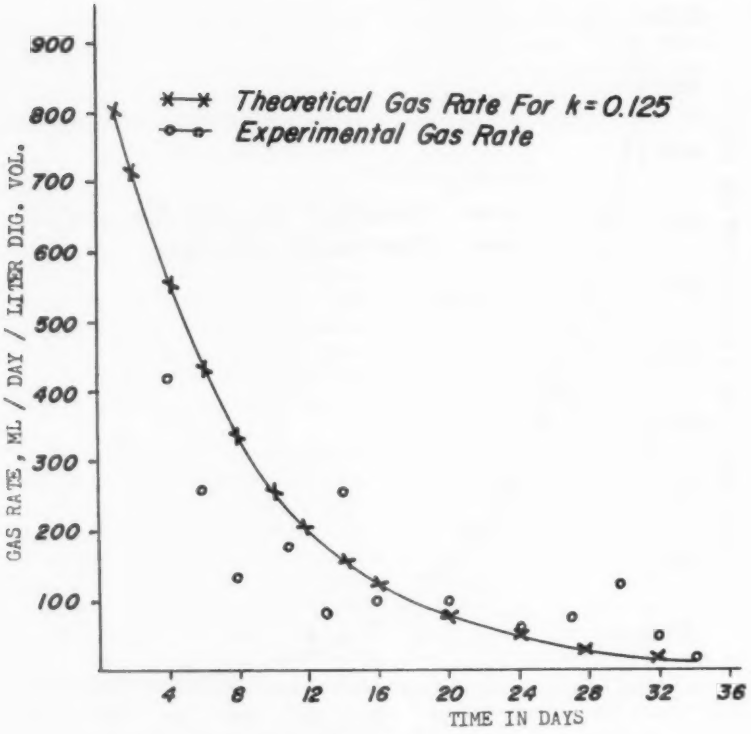

FIGURE 8.—Gas rate per 1,000 ml of active volume, unit No. 2.

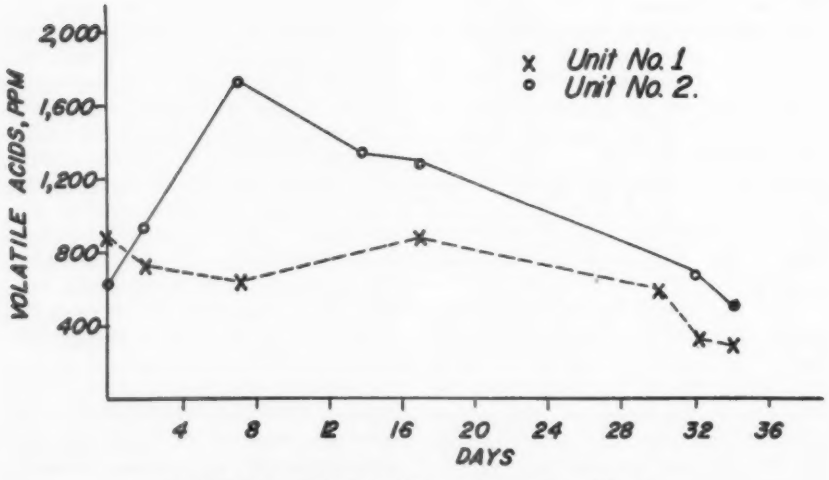

FIGURE 9.—Volatile acids in units No. 1 and No. 2.

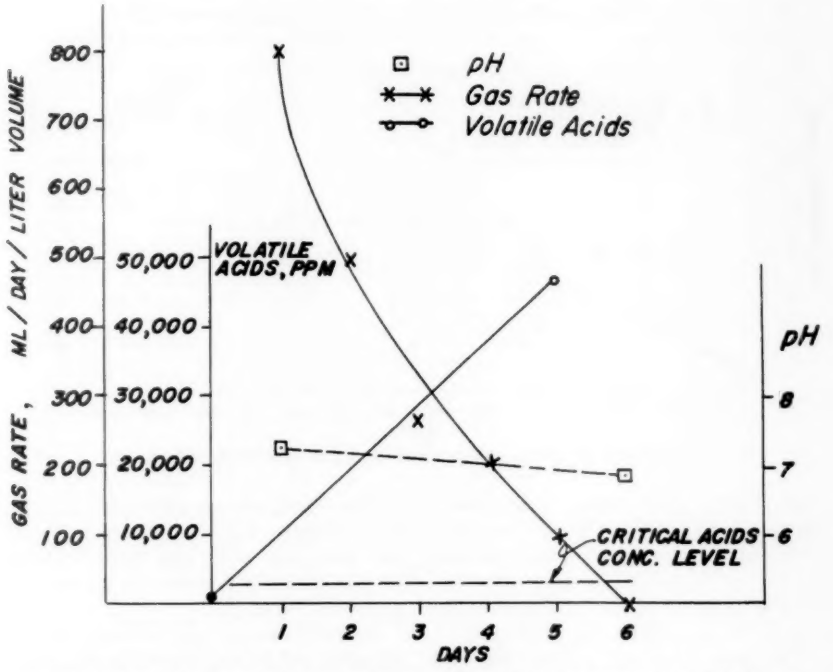

FIGURE 10.—Gas rate, pH, and volatile acids at 49.75 per cent solids, unit No. 3.

Use of Gradually Increased Solids Concentrations

According to the experiments described, 100 g of air-dried digested solids could be added to 1,000 ml of seeding material without disturbing the normal course of digestion, and 40 to 45 ml of gas could be expected per gram of dry digested solids added. An attempt was made to increase the solids concentration gradually by adding dry digested solids in increments of 100 g. The objective was to maintain methane fermentation at as near a normal rate as possible while the solids concentration was increased.

Eight units were used for these experiments. Two of the units were operated without interruption for 133 and 115 days, respectively. The results of these units are therefore given in detail as representative. Both units A and B were started with 1,000 ml of active digesting sludge from the digester of the East Lansing treatment plant. The analytical data for this material are given in Table II.

The air-dried digested sludge used as feed material was the same as that used in the previous experiments.

Unit A received an initial feeding of 282 g of dry digested solids at the start of the experiment. The analysis of the mixture is given in Table II.

On the 35th day, 95.2 g of dry di-

TABLE II.—Analytical Data for Starting Conditions

Item	Control	Digesters	
		A	B
Total solids (%)	4.86	24.1	12
Volatile matter (%)	43.26	40.5	37.3
Ash (%)	56.74	59.5	62.1
Volatile acids (ppm)	313	627	789
pH	7.2	7.4	7.2

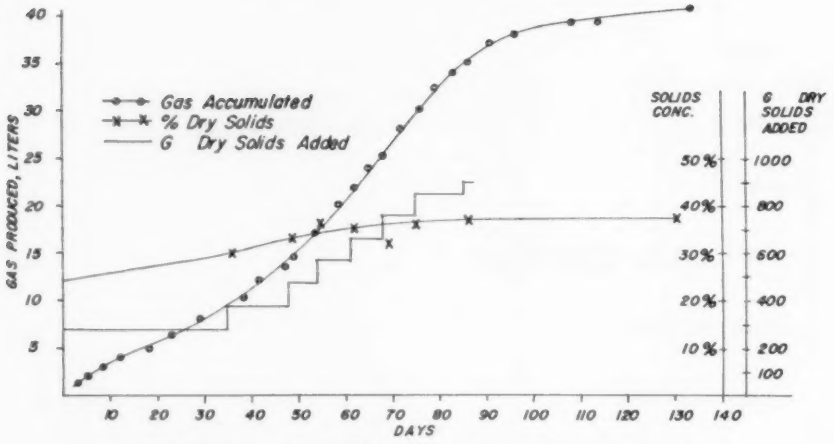

FIGURE 11.—Dry solids added and gas produced, unit A.

gested solids were added. Equal feedings were made on the 48th, 54th, 61st, 68th and 75th days, and a final feeding of 47.6 g on the 85th day. For the total of 900.8 g of dry digested solids added, 40.7 l of gas were produced.

The corresponding curves for gas accumulated, dry solids added, and solids concentration are shown in Figure 11.

The same data are presented for unit B in Figure 12. The analytical data for this unit after the initial adding of 100 g of dry digested solids are also given in Table II.

In this case, a total of 576 g of dry digested solids was added in six steps. The solids concentration increased from 12 per cent to 39 per cent and a total of 20.84 l of gas was produced.

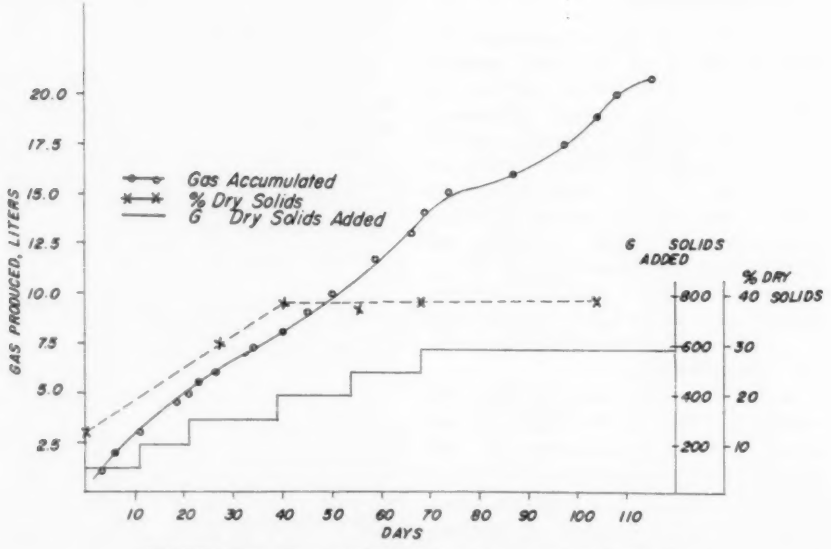

FIGURE 12.—Dry solids added and gas produced, unit B.

TABLE III.—Comparison of Gas Production, Gas Rates, and Feed Rates

Days	Dry Solids Added (g)	Volatile Mat- Added (g)	Average Solids Feed Rate (g/day)	Gas Produced Per Gram Dry Solids (ml)	Gas Produced Per Gram Volatile Matter (ml)	Gas Rate (ml/day)
			(*a*) UNIT A			
35	282.0	101.0	8.05	32.6	91	262
13	95.2	34.2	7.3	50.3	140	368
6	95.2	34.2	15.9	31.7	88	503
7	95.2	34.2	13.6	41.8	116	568
7	95.2	34.2	13.6	44.0	122	598
7	95.2	34.2	13.6	44.1	123	604
10	95.2	34.2	9.5	55.1	153	525
48	47.6	17.2	1.0	127.1	351	126
133	900.8	323.3	6.77	45.2	126	306
			(*b*) UNIT B			
11	100.0	35.9	9.1	29.1	81.0	264
10	95.2	34.2	9.4	21.0	58.8	198
18	95.2	34.2	5.3	28.9	80.4	152
15	95.2	34.2	6.3	28.9	80.4	183
13	95.2	34.2	7.3	27.8	77.5	204
48	95.2	34.2	2.0	81.9	228.1	162
115	576.0	206.9	5.0	36.3	101.0	181

Gas production was maintained as in unit A, but at a much slower rate.

For a comparison of the two units the data on gas production, gas rates, and feed rates for the individual feeding periods are tabulated in Table III.

According to the data for unit A, an average of 45.2 ml of gas was produced per gram of dry digested solids added, and an average of 126 ml of gas resulted per gram of volatile matter added. There is little change in these values if the solids contained in the seeding material are taken into account (48.6 g of dry solids, 21 g of volatile matter). The corrected values would be 42.9 ml of gas per gram of dry solids and 114.9 ml of gas per gram of volatile matter. These values are in good agreement with the 42.8 ml of gas per gram of dry digested solids, and 119 ml of gas per gram of volatile matter reported for unit No. 2 in the previous section. They indicate that the added solids have been actually digested to the same degree as in the batch experiments. By gradually adding dry solids it was possible, therefore, to obtain normal methane fermentation at solids concentrations up to 37 per cent.

In unit B the average gas production was only 36.3 ml per gram of dry solids added, and 101 ml per gram of volatile matter. Correcting for the 48.6 g of solids present in the original seeding material results in a gas production of 33.3 ml per gram of dry digested solids, and 91.4 ml per gram of volatile matter.

These values are considerably lower than those of unit A. The difference becomes more pronounced when the over-all gas rates are compared. These gas rates are not actual rates, but average values obtained by dividing the total amount of gas produced by the number of days. They are used for comparison purposes only. In unit A an average of 306 ml of gas was produced per day as compared with 181 ml of gas per day in unit B.

At first it was thought that the different feed rates would offer an explanation for the poor performance of unit B. To compare both units, the average feed rates for the individual feeding periods were plotted against the corresponding gas rates. The feed rates were obtained by dividing the weight in grams of dry solids fed by the number of days for each feeding period. The gas rates were obtained the same way, using the gas produced in milliliters per feeding period (Table III).

The data are plotted in Figure 13. The curves show that, up to a certain limit, there is a direct proportion between feed rate and gas rate. In unit A the gas rate increased to 600 ml per day with a feed rate of 13.6 g of dry solids per day. This appeared to be the optimum under the conditions described. A further increase in the feed rate to about 16 g of dry solids per day resulted in a lowered gas rate of 500 ml of gas per day. The curve for unit B shows the same relationship between feed rate and gas rate, but at a much lower level. For comparable feed rates only about one-half as much gas was produced per day.

Apparently the different feed rates applied did not offer an explanation for the lower gas rates in unit B. The pH in both units remained above seven throughout the experiment, varying between 7.2 and 7.8 in both cases.

A comparison of the volatile acids concentrations revealed that unit B, during most of the time, had more than 4,000 ppm of volatile acids, whereas unit A was operating at a range of 1,000 to 2,000 ppm of volatile acids. The data are tabulated in Table IV.

The average value for all volatile acids analyses made on unit A was 1,773 ppm, as compared to 4,347 ppm for unit B. From these data it appears that the different volatile acids concentrations were responsible for the different performance of the two units. Operating at an average volatile acids

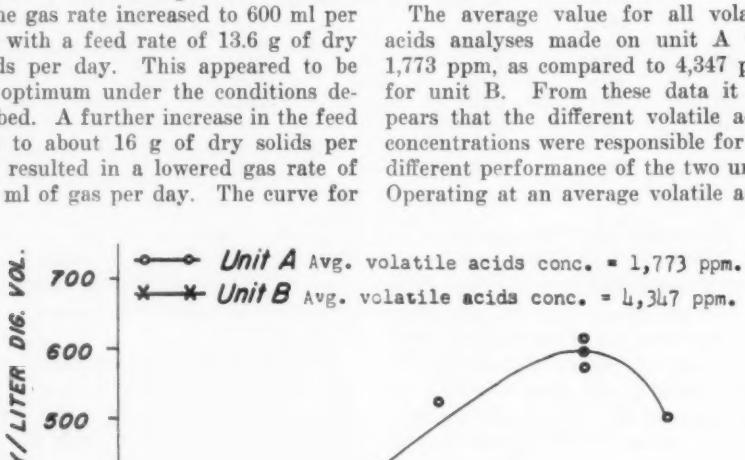

FIGURE 13.—Feed rate versus gas rate, units A and B. Effect of volatile acids concentration.

concentration of about 4,000 ppm reduced the methane production to approximately one-half its normal rate.

A simple averaging of the data on volatile acids over the complete run is a relatively crude method of analysis. However, it seemed justified in this case since after the 27th day the volatile acids in unit B consistently stayed above 4,000 ppm, whereas in unit A these high levels were reached on only two occasions, and then for only short periods of time.

A detailed check revealed a great deal of variation and sudden changes in the volatile acids concentration and the gas rate. This fact is demonstrated by Figures 14 and 15 which present curves for unit A and unit B, respectively. The daily readings of the gas rate and the volatile acids concentration are plotted against time in days.

Immediately after each feeding, gas rates increased by 200 to 300 per cent, followed by a steep decline during the next few days. These sharp peaks immediately after feeding were characteristic of both units.

In unit A an attempt was made to follow the course of the volatile acids formation more closely. A series of volatile acids determinations was made from day to day between the 60th and 80th days of the experiment. The data and the curve in Figure 14 show that the volatile acids concentration also is associated with the feeding cycle. There is a sharp increase in volatile acids concentration immediately after each feeding and a steep decline during the following days. The gas rate and the volatile acids curves parallel each other. Apparently during digestion the formation of volatile acids and the methane fermentation are operating simultaneously. The organic acids constitute the raw material for the methane production.

Thus the balance between the rates of acid and gas formation becomes an important factor. In a well-functioning digestion process the rate of acids conversion to methane has to be equal to or greater than the rate of acids formation. Otherwise the acids will accumulate. This accumulation, combined with the effect of a critical volatile acids concentration level above which the activity of the methane bacteria deteriorates, leads to a further accumulation of volatile acids, until a point is reached where the gas production ceases. Apparently in unit B the rate of acid production was greater than the rate of acid consumption or methane production. The critical period seemed to be the first 30 days.

Unit A received one initial feeding

TABLE IV.—Volatile Acids Concentrations, Units A and B

Days	Volatile Acids (ppm)	
	Unit A	Unit B
0	627	315
15	5,338	789
27	—	3,936
33	—	4,156
36	2,100	—
40	—	7,035
49	1,264	—
54	—	—
55	—	5,069
61	1,067	—
62	3,015	—
64	4,750	—
65	1,790	—
66	1,718	—
68	—	5,049
69	1,911	—
70	3,145	—
71	1,903	—
72	1,858	—
75	2,538	—
76	3,380	—
77	2,134	—
78	2,136	—
79	1,640	—
80	—	5,706
82	1,840	5,950
83	—	5,240
84	—	5,310
86	2,284	—
100	1,920	4,402
113	1,270	—
118	—	3,540
128	1,293	—
Avg.	1,773	4,347

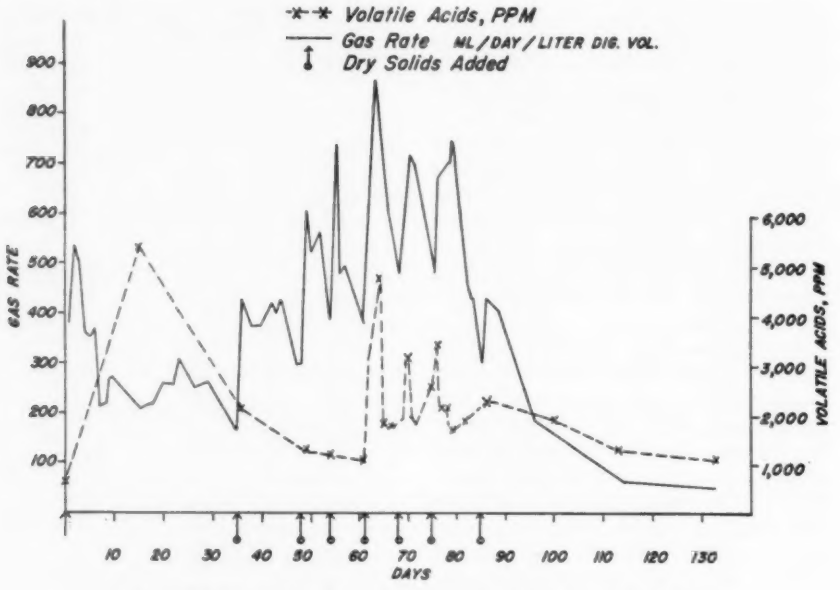

FIGURE 14.—Volatile acids concentration and gas rate, unit A.

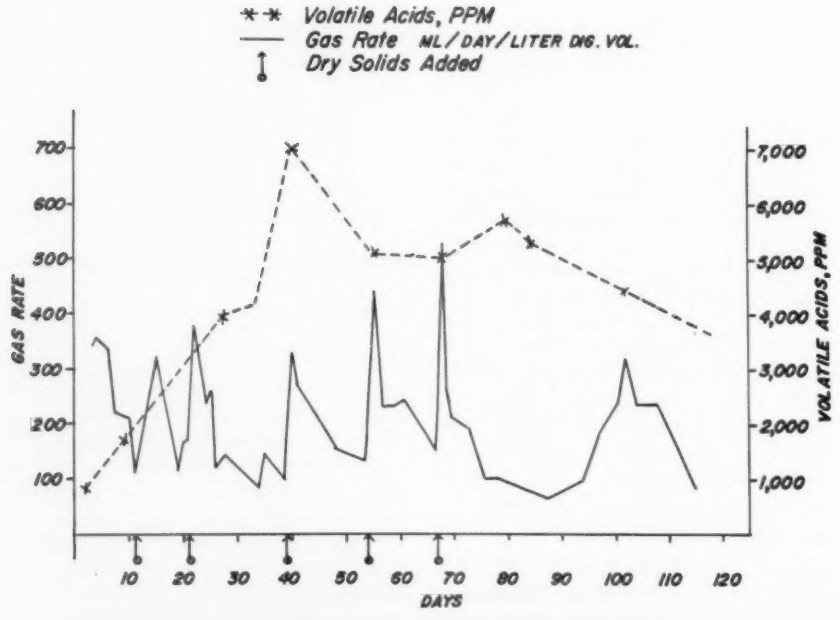

FIGURE 15.—Volatile acids concentration and gas rate, unit B.

of 300 g of air-dried digested solids. The next feeding was done on the 35th day. At that time the volatile acids were steadily decreasing and the gas rates were 368, 503, 568, 598 and 604 ml of gas per day (Table III*a*). Unit B received three feedings each of 100 g of air-dried digested sludge during the first 21 days. However, in this case the volatile acids concentration increased steadily and stayed at a relatively high level throughout the experiment. The average gas rates for the following three feeding periods were 152, 183, and 204 ml per day (Table III*b*).

The low rate of gas production in unit B cannot be explained by stating that the digester was overloaded. On the contrary, the average feed rates were lower than those for unit A. Therefore, the basic question still remains: which came first, a depression in methane production resulting in an accumulation of volatile acids, or an increase in volatile acids production resulting in an inhibition of methane fermentation? It is understood that any reduction of the methane fermentation automatically leads to an increase in volatile acids concentration. The problem is: does an increase in volatile acids concentration above a given level actually cause a reduction of methane fermentation? Apparently the problem cannot be decided by the type of experiment described herein.

There appears to be a better way of reaching a decision as to this problem. First, a series of laboratory digesters could be established with a known fermentation activity; for instance, a known capacity for converting volatile acids to methane. This could be accomplished by feeding these units with known amounts of organic acids such as acetic, propionic, or butyric. Second, once the activity had been established, the volatile acids concentration in the unit could be increased in a controlled manner and the effect on gas production investigated. This would exclude the possibility that the increase in volatile acids concentration was merely the result of a low fermentation activity. The experiments conducted according to this plan will be described in the second part of this paper.

Summary and Discussion

In all batch experiments in which a relatively small amount of seeding material was mixed with dry raw sludge to establish solids concentrations from 10 to 50 per cent, gas production decreased to zero after six days. The principal process in these concentrated sludges was the production of volatile acids. Concentrations ranging up to 54,000 ppm volatile acids, as acetic acid, were reached at a dry solids concentration of 51 per cent, after an 80-day period. Changes in pH were minor due to the buffering capacity of the sludges. Only in one case, at 51 per cent dry solids, did the pH drop below six.

Attempts to increase the solids concentration gradually by adding dry digested sludge as feed material were successful. Methane fermentation was carried on at normal rates of gas production up to 37 per cent solids, as long as the volatile acids stayed in a range of 1,000 to 2,000 ppm. A unit operating under similar conditions at up to 39 per cent solids produced only about one-half as much gas per day for corresponding feed rates when the average volatile acids concentration was greater than 4,000 ppm.

Detailed analysis showed that the volatile acids formation was associated with the feed cycle. Immediately after feeding there was a sharp increase in volatile acids, followed by an equally sharp decline during succeeding days. This confirms the hypothesis that during digestion (both processes) the formation of volatile acids and the methane fermentation are operating simultaneously. The organic acids pro-

duced by one group of anaerobic bacteria constitute the raw material for the next group of organisms, the methane bacteria. It is known (6) that bacteria of the genus *Clostridium* produce formic, acetic, propionic, and butyric acids from a wide variety of organic substrates. They grow under strict anaerobic conditions and probably constitute the first group of organisms in the mixed culture existing in digesting sludge.

Anaerobic sludge digestion, therefore, consists of a balanced process where the rate of acid formation is kept equal to or below the rate of methane fermentation by maintaining temperature, pH, and feed rates near the optimum for methane bacteria. Feed rate seems to be the most important of these factors.

From the high volatile acids concentration regularly reached in the concentrated sludges, it can be concluded that the acid producers are much less sensitive than the methane bacteria. They are not easily affected by variations in pH, temperature, or moisture, or by an accumulation of their own metabolic products. Accordingly, they become predominant whenever adverse conditions occur and especially when organic matter is present in a concentrated form.

This reasoning leads to an interesting parallel with regard to the disposal of city refuse and garbage by burial or sanitary landfill. Here also, there is organic matter in concentrated form under anaerobic conditions. Temperature and moisture are subject to great variations and in most cases are not near the optimum for methane bacteria. Still a certain amount of methane fermentation takes place. Gas analyses taken from New York landfills (7) averaged 30 per cent carbon dioxide, 45 per cent methane, 3 per cent oxygen, and 22 per cent nitrogen. It is known that decomposition in the deeper layers of such material proceeds slowly. Hering and Greeley (8) cite that at a garbage disposal location at Champaign, Ill., the material, after being in the ground for 12 years, was still not decomposed and had a foul odor. Garbage from the city of Rome, Italy, buried about 1,000 years ago at a depth of 25 to 30 ft, had not completely decomposed.

In the light of the conclusions presented here, it appears that the disposal of city refuse and garbage by burial or landfill creates conditions favorable for the predominance of acid producers. The high concentrations of organic acids accumulated make the material resistant to further breakdown by methane bacteria. Something similar to a silage process, a natural preservation against further attack by other groups of microorganisms, takes place. Unfortunately no references could be found on the volatile acids concentration in samples from sanitary landfills.

Since excessive formation of organic acids appears to be the block in the anaerobic breakdown of concentrated organic matter, it would be interesting to investigate the possibility of inhibiting the acid producers. If an agent could be found which specifically decreases the rate of acid production without harming the methane bacteria, this would allow an experimental verification of the hypothesis developed here.

From a practical point of view, the possibility of digesting sludges with a solids content ranging from 30 to 40 per cent seems quite remote. Pumping and stirring of this paste-like material would be difficult and power requirements would be excessive. Another difficulty would be the dewatering procedure prior to digestion. At present, raw sludges can only be dewatered by the addition of chemicals such as lime and ferric chloride. In one experiment raw sludge from the East Lansing sewage treatment plant was prepared by

adding 5 per cent lime and 1 per cent ferric chloride on a dry solids basis and dewatering on a vacuum filter. The sludge cake from the filter had a moisture content of 76 per cent, and was air-dried to 8 per cent moisture. After grinding, 19.3 g of this material was added to 1,000 ml of seeding material.

In contrast to the control units, where gas production started immediately, no gas was produced for an eight-day period. After this period, gas was produced at the relatively slow rate of 45 to 75 ml per day. In a 28-day period only 23.5 ml of gas per gram of dry solids was formed. This is in agreement with the work of Keefer (9) who found that the digestion of sludge treated with ferric chloride was considerably delayed, and that the gas yield was reduced by increasing the solids concentration. His curves show that digestion of sludges containing 15 per cent and 32 per cent solids was not complete after a 70-day period. Bacteriologically, ferric chloride is a strong poison. Salle (10) states that ferric chloride is toxic for *Escherichia coli* in a concentration of 0.001 molar. According to this information, digestion and methane fermentation of chemically treated concentrated sludges does not appear feasible.

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FOURTH NUCLEAR ENGINEERING AND SCIENCE CONFERENCE

More than 30 leading engineering and scientific societies, including the Federation, are sponsoring the Fourth Nuclear Engineering and Science Conference to be held in the Chicago Amphitheatre, Chicago, Ill., March 17–21, 1958. The Conference is the main technical feature of the 1958 Nuclear Congress. Technical exhibits and other meetings are planned. Conference programs are available to Journal readers upon request from the Federation office.

Industrial Wastes

PLANNING A WASTE SURVEY *

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Experience with control of industrial pollution has shown that the principal differences between it and the control of pollution from municipal sewage are the widely varying qualities of industrial wastes as contrasted with the universal nature of sewage, and the everchanging pattern of industry's operations as contrasted with the regularity of human dietary and environmental habits. In other words, industrial wastes vary from plant to plant, whereas the type of pollution from sewage is unchanged in major characteristics from locality to locality. Furthermore, industry is continually adjusting its processes to supply varying consumer demands, whereas changes in the living habits of people occur gradually and over relatively long periods of time.

These dissimilarities cause emphasis to be placed in different places in the pollution control programs for industry as compared with municipalities. An industrial process which may be outmoded at any time by competition, or the changing tastes of consumers, is not best served with a treatment plant with long life expectancy built into it; but forty years of useful service is the basis on which financiers advance money for construction of sewage plants. Industry finds that the most satisfactory and effective approach to its problem is to adjust its operations internally so as to reduce its pollution to the point where the conventional processes of equalization, neutralization, sedimentation, skimming and diffusion will provide adequate treatment. Such treatment is useful in all types of industrial waste water disposal and may be installed with assurance that its useful life expectancy will be realized. Although it will provide satisfactory control of sludge deposits, "slugging," and harmful pH fluctuations, it will not in itself provide adequate control for the toxicity, discolorations, high BOD, or mineralization factors characteristic of many industrial waste problems.

The control of this latter group of pollution factors demands special survey attention which, to be successful, must go beyond customary effluent survey procedure. It must, by proper means, look into processing plans, the schedules of production, the sacred seclusion of research, and prepare itself for budget justification.

Pollution Control a Part of Planning

American Cyanamid's policy requires that new processes, expansions and future planning be reviewed for the adequacy of stream pollution control steps by a group empowered to

* Presented at the Florida Industrial Wastes Workshop; Lakeland, Fla.; Aug. 12–14, 1947.

act. Research personnel must anticipate pollution control steps in developing new processes, and engineering does not proceed until pollution questions have been satisfactorily answered.

Out of the planning of various groups for new plants or expansions are developed estimates of costs of pollution control. These are included in projected operating costs for the new facility, thus insuring that pollution control will be a part of day-to-day operations.

Close cooperation with state and duly authorized civic bodies dealing with pollution control is another phase of the company's progressive approach to this vital factor in its relationships with plant communities. This attitude has earned the company a reputation for leadership in the development of pollution control for its new installations.

For existing plants the company's usual mechanism is to place responsibility on each local plant manager for keeping pollution under control and to provide him with such technical assistance as he requests—including the application of new pollution control systems as they are developed.

An Example

The Brewster, Fla., plant is an example of industrial pollution control. Here, since 1915, the company has mined, washed and graded phosphate ores. The waste wash waters pose a slime and stream siltation problem that was solved by local management through the installation of a system of clarifying lagoons through which the waste waters are slowly passed. The clay and sand which cause the stream pollution from phosphate mining are retained in these lagoons and the effluent is exceptionally clear.

Control of stream pollution at Brewster is a permanent program under the direct and personal supervision of the local manager. Lakes and streams in the area are a particular source of local pride, and there is grave concern over the possibility of pollution. This means that the control systems must be kept under constant supervision, and there must be on hand accurate data concerning the release of effluent into public waters.

Plant management at Brewster has consistently demonstrated its willingness to discuss and permit inspection of its pollution control systems by state officials, public groups, and the press. This policy has gone a long way toward convincing the public that the company recognizes its obligations to the community in control of pollution.

In other words, it is considered basic to an approach to stream pollution to take steps to control effluents, to study constantly and record data on the control program, and to let the state and the public know what is being done.

New Problems with Fluorides

Recently, the job of controlling pollution at the Brewster plant was amplified when the manufacture of triple superphosphate was commenced. While this plant was being designed, particular attention was given to stream pollution that might result from this operation; the principal concern was with fluorides which would be in the wastes and which occur naturally in the phosphate rock deposits underlying much of the surface in the area. Because of the rather high toxicity of fluorides to fish and livestock, it was necessary that the effluent be treated to remove the possibility of stream pollution. Such treatment was made a part of the project and is now in operation at Brewster.

Simple Sampling Stations

Particular stress has been placed on the monitoring of stream conditions, both above and below the outfall. The program began about one year before the new operation was started and is being continued. Today three automatic sampling stations are in service:

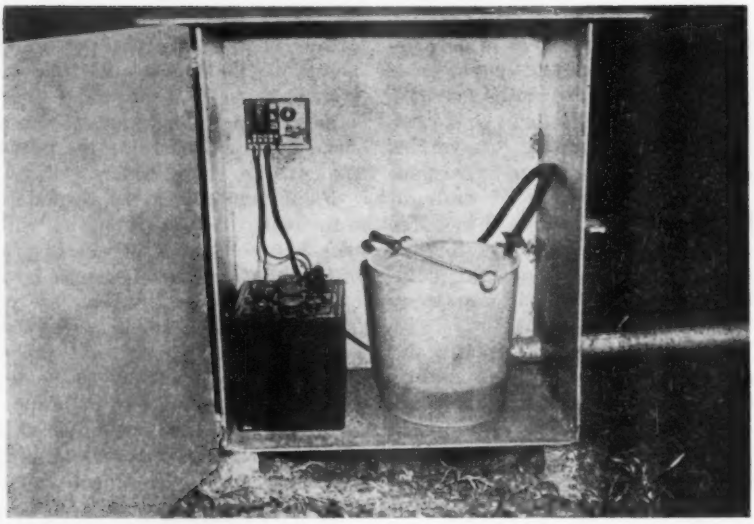

FIGURE 1.—All-metal welded shelter houses simple but efficient and inexpensive, automatic, battery-operated sampling station.

on the effluent outfall, on the stream above the point of effluent entry, and on the stream below the effluent entry.

This equipment was developed specially for the Brewster job and represents an improvement over the type used by the company for a number of years.

This battery-operated unit (Figure 1) is placed on the side of the stream and its sample is withdrawn from the stream from beneath an anchored float that can be positioned wherever desired. The battery operates a motor and pump that deliver a predetermined volume of water to a receiver every 15 min. A unique timing device operates the pump and motor. The timer is adjustable to give collection of any desired water volume during any particular time interval. Samples so collected may be composited for subsequent analyses. The battery-operated feature permits the sampler to be located where power is not available, and the automatic feature substantially eliminates the labor of sampling.

In addition to installing modern control systems, the company has made it a practice to be frank on the question of pollution control, to exchange technical information with others in industry, to keep regulatory authorities and the community informed of its progress in pollution control, and to welcome the establishment of reasonable standards and methods for the control of pollution under state auspices.

Santa Rosa Plant

An example of new facility pollution control planning is the Santa Rosa plant, now under construction on the eastern shore of Escambia Bay near Milton, Fla. Its case history of pollution control will illustrate this approach.

This plant will make Creslan * acrylic fiber from acrylonitrile through a series of steps involving polymerization and wet spinning. It will draw its water supply from the aquifers underlying the site and will discharge its waste waters offshore into Escambia Bay.

Nearly all of the raw materials used

* A registered trademark of American Cyanamid Co.

in this process will emerge from the plant as products or will be recovered for re-use. But there will be some losses to the sewers and these losses presented a problem of pollution evaluation. This is a new fiber with certain unique properties. Likewise, the pollution problem involved in its manufacture is unique. There was no precedent to point the way and the problem had to be worked out along with the development of the manufacturing process.

The job of planning an effective program of pollution control actually began more than five years ago, long before the company made its final decision to produce its own fiber. At that time, Cyanamid's Stamford (Conn.) Research Laboratories was the site of a pilot plant in which an acrylic fiber was being experimentally produced by a wet-spinning technique similar to that which will be employed in the new Santa Rosa plant.

The first key to the effluent problems associated with this fiber came when the City of Stamford reported that sewage from the company's research laboratories had increased consumption of chlorine at the municipal plant. Investigation showed the source of the problem to be the fiber pilot plant, and the pollutant causing the high chlorine demand to be a water-soluble thiocyanate.

Research solved the immediate problem through special internal treatment of the pilot-plant effluent. It also recognized the importance of the matter by placing pollution control on the acrylic fiber development agenda. Methods of disposal of thiocyanate wastes were studied and a literature reference was found to a specific bacterium which Happold and Key (1) had isolated in England from sewage slimes which were found to be oxidizing thiocyanate wastes.

Stamford personnel wrote to Happold and received a culture of his organism, *B. thiocyan oxidans*. Experiments showed that it would grow in the wastes and destroy the chlorine demand.

Research then turned the matter over to the engineering section for preliminary planning and rough estimates. The question was asked: "What data would be required for plant site evaluation for effluent disposal?" A comprehensive study of the problem as a whole was requested.

This was granted and the customary pollution criteria—solids, BOD, toxicity, color, pH, and odor—were determined at Stamford and at The Johns Hopkins University. Johns Hopkins-type tubular filters (2) were installed at Stamford for collecting order-of-magnitude data. Early in the work with this unit it was found that Happold's organism, isolated from sewage in England, was also present in the soil of the Stamford lawn. Therefore, special seeding with *B. thiocyan oxidans* would be unnecessary.

Subsequent work at Pearl River has shown that this bacterium is present in all of the natural waters used there in the Creslan effluent work, including Escambia Bay water. This means that it will be possible to make a reasonable use of the assimilation resources of the receiving waters.

The conclusions from the early laboratory work enabled preparation of tentative effluent disposal requirements for plant site selection use and that phase of the project commenced.

Research continued its work on the fiber process; in due course, serious planning was commenced for a manufacturing plant using an improved process. Engineering was asked to devise a program which would yield firm data for plant site selection. Accordingly, the work was "farmed out" to the Lederle Industrial Waste Laboratory at Pearl River, N. Y., and to The Johns Hopkins University. The following questions were proposed:

1. What is the true BOD of this effluent?
2. What is its assimilation behavior?
3. Is its sludge toxic, or putrescible?
4. Will the pollutants, or the sequela of their biological oxidation, cause an odor in the receiving waters to affect water supplies or fish?
5. What is the toxicity of this effluent to fish?
6. Will this effluent discolor the receiving waters?

It was felt that firm answers to these questions would provide management with the information it had requested. Considerable progress in the method-

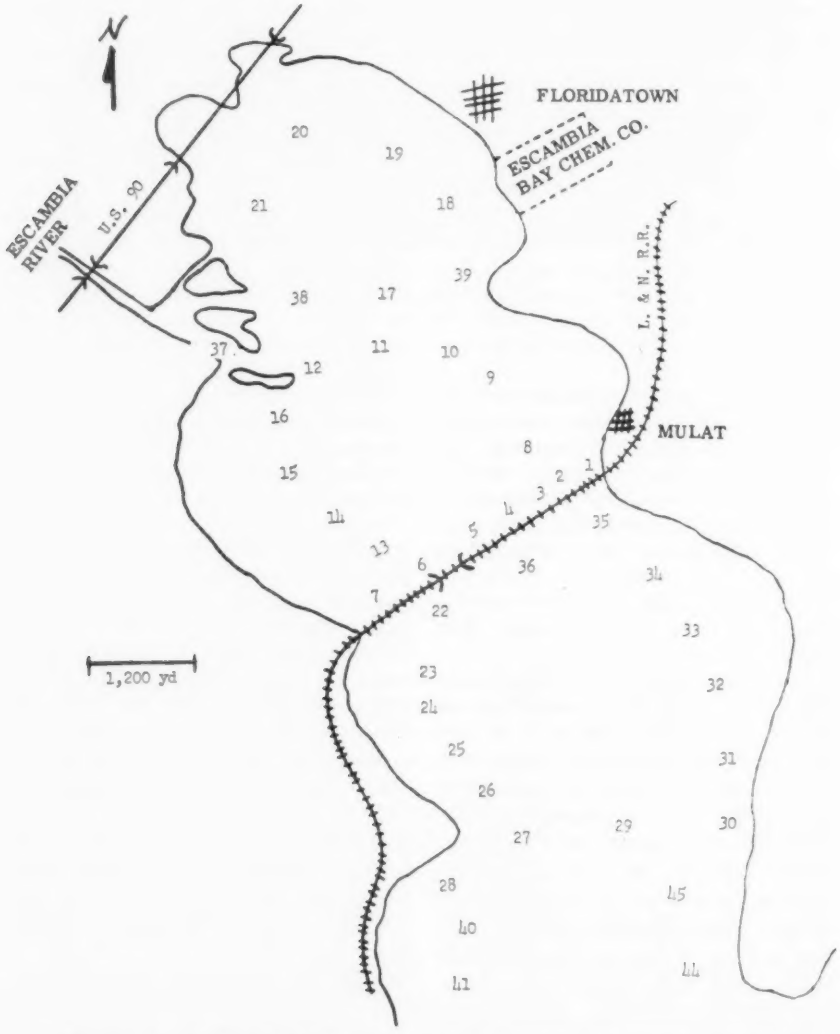

FIGURE 2.—Location of sampling stations, Escambia Bay survey, May and September 1956.

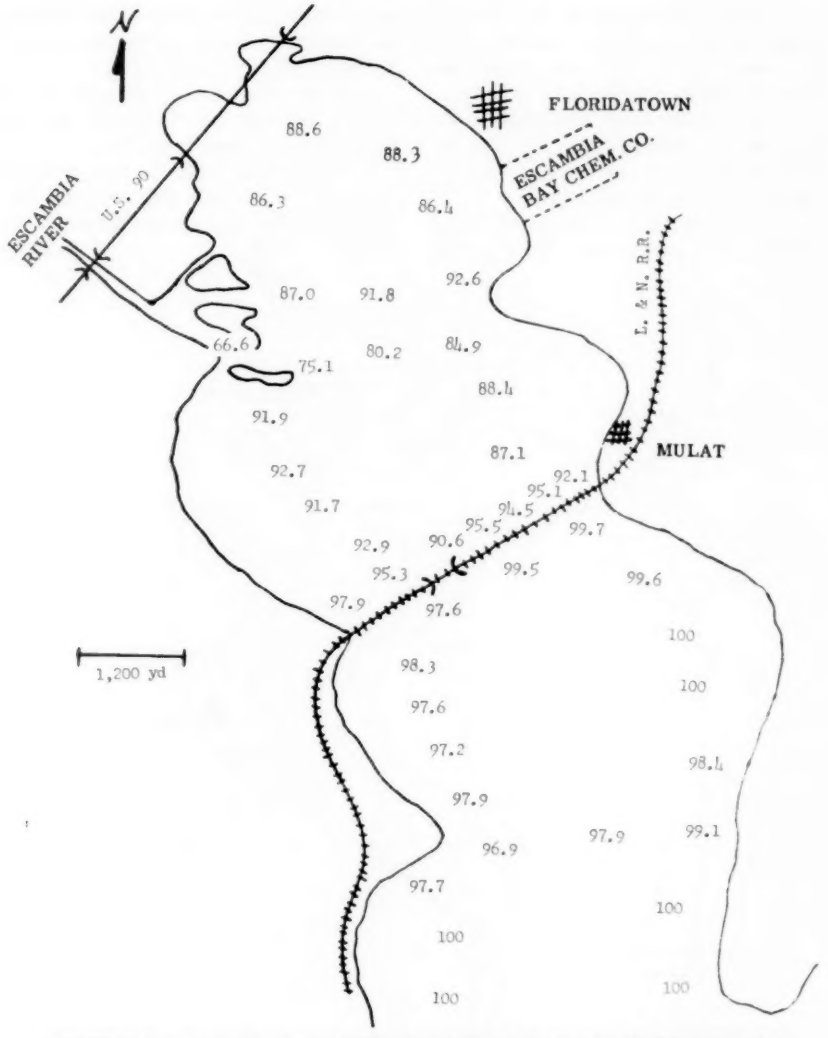

FIGURE 3.—Average per cent DO saturation, April 24 through May 30, 1956.

ology of industrial pollution measurements had been made since the early work, and it was possible to be more specific in these later studies.

Considerable aid was gained from the information published by Lamb and Jenkins (3) on BOD values for synthetic compounds, by Mills and Stack (4) on BOD techniques, by Cherry, Gabaccia, and Senn (5) on assimilation behavior techniques, by Daugherty and Garrett (6) on the toxicity of organic cyanides, and by Renn (7) on biological tolerances of acrylonitrile and related compounds. This phase of the work was completed in 1956. The findings were:

1. The BOD of the wastes would, at its worst, be from 2½ to 3 lb of 5-day BOD per 100 lb of fiber produced.

2. About two-thirds of the total organic carbon would be assimilated by the receiving waters and about one-third would be unaffected.

3. The sludge from the fresh unsettled effluent was toxic to fish. The settled effluent was not of toxic significance. The sludge was stable.

4. The threshold odor of the total effluent, when dispersed in odor-free water, was 1 in 200,000. After biological assimilation this odor was reduced by about 50 per cent.

5. Fish tolerated 15,000 ppm of the settled effluent for extended periods without toxic manifestations.

6. The settled effluent was without apparent color and produced no discoloration in the assimilation study bottles.

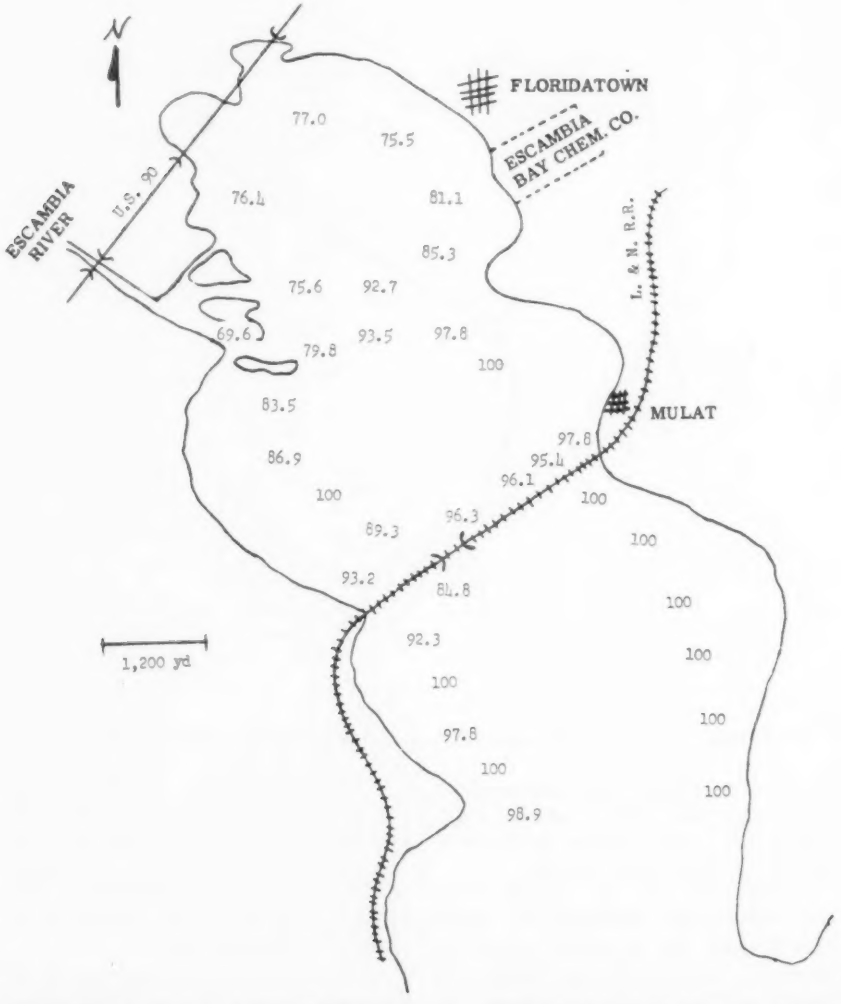

FIGURE 4.—Average per cent DO saturation, September 18 through September 22, 1956.

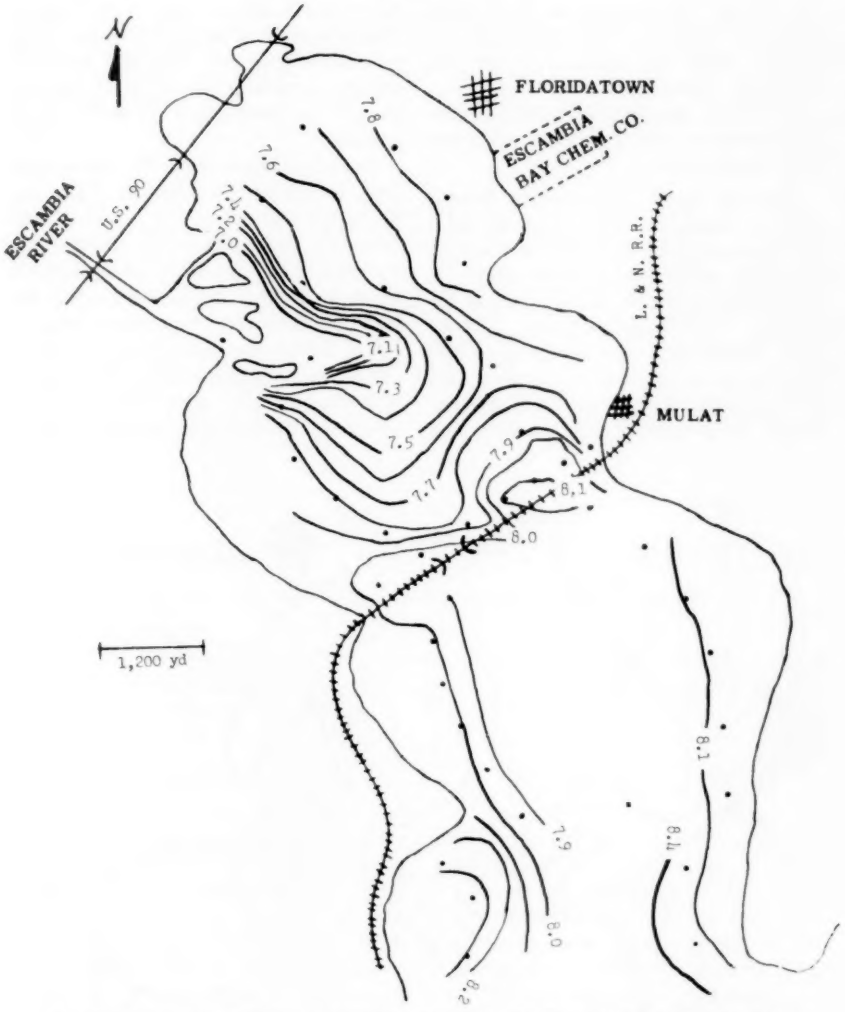

FIGURE 5.—Dissolved oxygen profile (in ppm), April 24 through May 30, 1956.

Consideration of these data caused the drawing of conclusions which may be summed up as follows:

1. Regardless of the site selected, the acrylic fiber wastes must be well equalized and receive primary treatment. Further, the settleable and flotable solids so removed must be retained behind permanent and non-floodable dikes.

2. If the site selected has a minimum of 500 cfs flow of diluting water in the receiving stream, no further reduction of BOD is needed in addition to primary treatment.

3. If these minimum diluting requirements for BOD are provided, there will be no difficulties with fish toxicities, or with odors in the receiving waters.

4. When site selection has been made, the validity of the biological conclusions must be established for the receiving waters.

5. Sludge impound odors and stream discolorations will not be a problem with these wastes.

Thus by these means, after several years of work, by 1956 a logical basis had been acquired for effluent disposal judgment of proposed plant sites. A number in which management was interested were found suitable. Others were dismissed. Management looked with favor on the Pensacola area site on Escambia Bay and asked if flowing stream data could be interpreted for this tidal estuary. The reply was affirmative with a judgment opinion, but it was pointed out that the dissolved oxygen recovery resources of the bay should be determined in order to be certain.

Both the time and the appropriation were granted. In late April and May, and in September 1956, a team from the Pearl River laboratory made surveys of the bay daily from Monday through Friday each week and also brought Escambia Bay water back to Pearl River for validation checks of the biological conclusions. The assimilation behavior of these wastes in fresh water was found to be confirmed in the

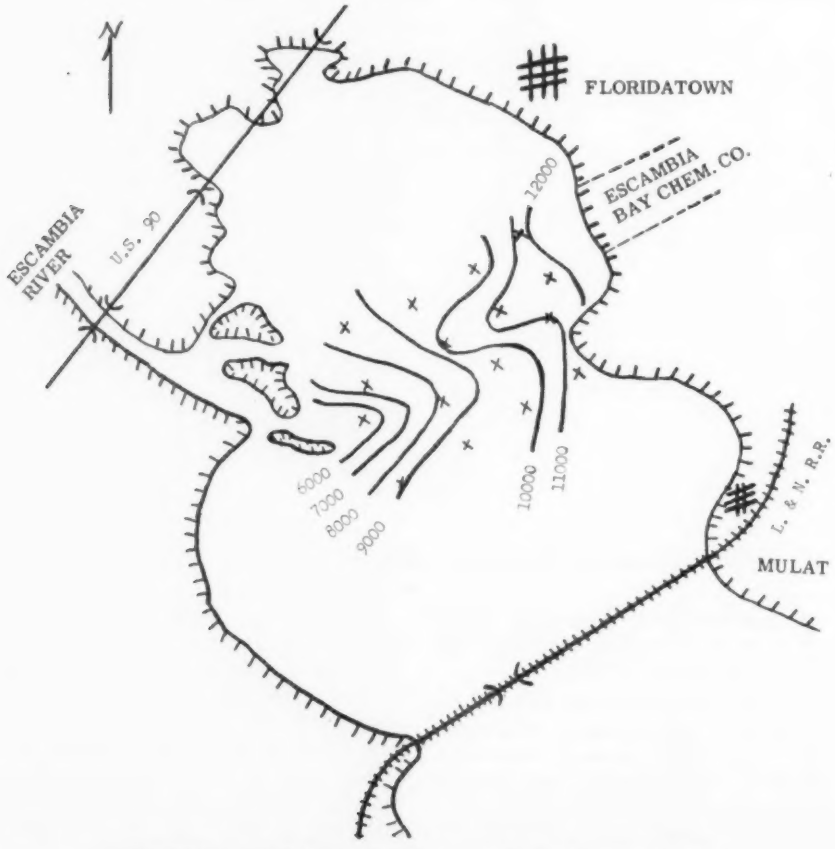

FIGURE 6.—Salinity profile (in ppm), September 20–21, 1956.

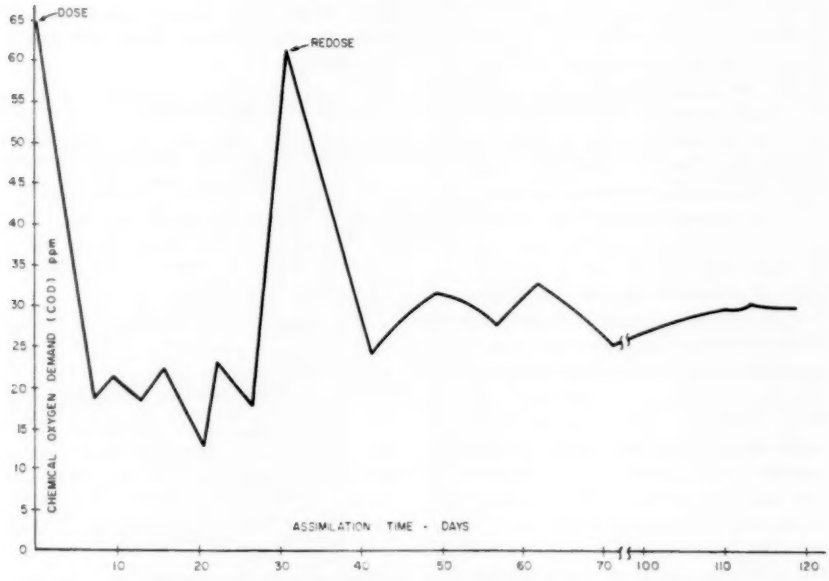

FIGURE 7.—Assimilation behavior of Creslan wastes, 1955–56.

saline Escambia Bay water. The dissolved oxygen and salinity survey data are shown in Figures 2 through 6. Figure 2 shows the sampling stations established in the bay. Figure 3 shows the average dissolved oxygen values found in the April–May survey, expressed as per cent saturation; Figure 4 shows these values for the September survey. Figure 5 shows the dissolved oxygen profile of the bay during the April–May survey period. Figure 6 shows the salinity of the upper bay during the September survey period.

Figure 7 shows the assimilation behavior curve for the Creslan acrylic fiber wastes. It will be noted that not all of the Creslan acrylic fiber COD was biologically consumed. Further, that on subsequent redosing, the COD residuals tended to "plateau" at a higher level, indicating an unassimilable fraction. The studies show that this is about one-third of the influent COD. (This phenomenon is not unusual in industrial waste work. Not all organic compounds are relished by the biota. The classic example is oxalic acid and its salts; although it is made commercially by biological processes, it exhibits no BOD in natural waters.)

It was concluded that there were ample dissolved oxygen resources in the bay; that the primary reaeration effect was from wind action ruffling the bay waters; that the diurnal effects were secondary to those of the winds; and that the salinity of the upper bay indicated a good tidal exchange.

Management selected the Escambia Bay site and the data, judgments, and conclusions were presented to the Florida State Board of Health. Facilities are now being designed for the disposal of sanitary sewage and industrial wastes to fit the problem as now understood and to meet the state requirements.

These will include primary treatment, sludge digestion, disinfection, and lagooning of the sanitary sewage and cafeteria wastes. The industrial waste waters will be neutralized, equalized, settled, skimmed, and la-

gooned. The sludge and scum will be retained on shore behind permanent dikes. The lagoon effluent will be diffused into Escambia Bay in a 1,500-ft wide zone about 1 mile offshore. The BOD of the effluent will be kept within assimilable limits through internal steps, principally recovery and re-use.

In retrospect, it is felt that this approach of alert caution has been in the best interests of the people of the State of Florida and of the company. A comprehensive study has been made of this problem because time was made available to do so by the early attention of research to the pollution phases of a proposed new process and, of equal importance, the backing of management was extended at all times.

If there has been any error in the interpretation of the data, or if any essential factors have been overlooked, it is felt that the excellent understanding of the process, and the knowledge of the biological behavior of the wastes, will enable making any necessary further provisions to comply with the company's understanding with the state—that there be no pollution of Escambia Bay waters from the Santa Rosa plant.

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YOUR LAST ISSUE?

The January issue of SEWAGE AND INDUSTRIAL WASTES will be the last issue received by many of the members. The reason—their names will have been removed from the Journal mailing list for non-payment of 1958 dues.

To assure continued receipt of the Journal, Member Association dues must be paid promptly. Reinstatement is time-consuming and costly to the Federation and its members. In addition, each extra handling of a member's record multiplies the chance for error. Refer to page 4a of this issue for the name and address of the secretary of your Member Association.

Your immediate payment of 1958 dues will be appreciated.

POLLUTION CONTROL AT SHELL OIL REFINERIES*

By L. C. Burroughs and G. E. Sample

Respectively, Assistant to the Vice President, Manufacturing, Shell Oil Company, New York, N. Y.; and Pollution Control Chemist, Shell Oil Company, Wood River, Ill.

In order to understand the waste treatment problems of a modern petroleum refinery it is first necessary to be familiar with the general production aspects of refinery operation. About forty years ago petroleum refining was comparatively simple. The crude oil was separated by distillation into only a few products, that is, gasoline, naphthas, kerosene, fuel oils and lubricating oils. Most of these were immediately ready for sale; however, it was necessary to use chemical treatment for some products to make them of marketable quality. Fairly large volumes of water were required for cooling and processing purposes. The major problem from the standpoint of stream pollution was to prevent oil from passing from the refinery with outflowing waste water.

In recent years refining technology advancements and higher quality product demands have intensified the refiner's pollution problems. Because of availability considerations, refineries must process larger amounts of high sulfur content crude oil. The crude oil today is distilled to obtain a relatively large number of short boiling range fractions. These, in turn, may be subjected to a number of processes before becoming suitable for sale or for blending into finished products; for example, a light fuel oil suitable for home heating is frequently processed to yield essentially 100 per cent of gaseous constituents and high octane motor gasoline. A large portion of the gas is further processed into high octane gasoline suitable for aircraft or automobile consumption. Some of these processes are termed "catalytic cracking," "alkylation," "polymerization," and "isomerization." The number of petroleum products required from a single refinery to meet modern automotive, industrial, and other needs may exceed 1,000.

The changing production pattern in line with higher quality product demands has created a substantial increase in the sources and types of wastes. The oil industry in general has kept pace by constant study and investigation to obtain answers to these problems. The American Petroleum Institute Committee on Disposal of Refinery Wastes has been active for nearly thirty years in developing waste disposal methods and publicizing these methods through issuance of manuals.

Oil Separation

To prevent stream pollution all oil refineries are equipped with gravity type, oil-water separators. Oil-bearing waste waters are passed through one or more of these separators before being discharged from the refinery. As a result of much investigative work and research carried out at various universities, oil-water separator efficiencies have been improved greatly through the years. While for economic reasons it is not feasible to replace all of the inefficient separators operating today in refineries, most of those installed or altered during the past ten years or so are reasonably efficient if not subjected

* Presented at the 1957 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Chicago, Ill.; June 26–28, 1957.

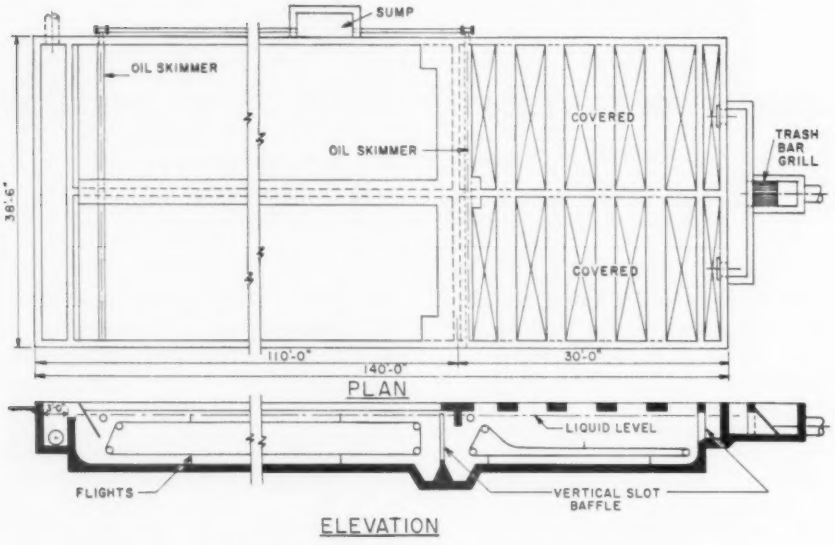

FIGURE 1.—Details of oil-water separator.

to emulsions or oil-water mixtures not susceptible to gravity separation. In recent years Shell installed a separator of new and improved design at their Anacortes, Washington, refinery (Figure 1).

This separator was designed to handle a normal flow of 2,000 gpm, with extra capacity for periods of heavy rainfall, and for allowance to take half of the separator out of service for emergency repairs or revisions.

The water enters the separator through a bar-type trash rack which intercepts pieces of floating wood and other debris. The water then splits and enters the separator proper which is divided into two channels, each 6 ft 2 in. deep, 18 ft wide, and 130 ft long. The water entering the separator strikes an impingement baffle and is then forced to flow with comparatively little turbulence into the separator between vertical posts which are spaced to give good distribution across the entrance end of the channel. Thirty feet downstream from the entrance gate is a curtain wall extending about 1 ft below the water surface. This wall serves to confine the lighter, more volatile oils separating and rising to the surface in the first portion of the separator, which is covered to prevent loss of gasoline by evaporation. Experience has shown that about 95 per cent of the oil separates in the covered portion of the separator. This part of the separator is equipped with a slotted pipe skimmer for oil removal and a flight scraper device that pushes separated solids from the bottom to a sludge sump from which they are removed intermittently by pumping.

Water passes from the covered portion of the channel under the curtain wall and through the 100-ft length of open channel, then under the oil retention baffle and over a weir which controls the water depth in the separator. This open section is equipped with a flight scraper for bottom sediment removal, the flights also serving to push oil on the water surface back into a slotted pipe skimmer near the oil retention baffle. The second part of the separator has considerable length to

provide time necessary for the separation of heavier oil particles whose rising characteristics are relatively slow. The separator was designed with a minimum of baffling in an effort to establish the best quiescent flow conditions with maximum detention time.

General Control Procedures

While every refinery is confronted with the problem of removing oil from waste water, many other controls must be maintained to insure that the effluent does not create objectionable conditions in the receiving water or impair its usefulness for required purposes. The great variation in control methods in refineries depend on such factors as: (a) nature of crude oil, (b) processing methods, (c) products manufactured, (d) use of once-through or recirculating cooling water, and (e) nature of waters into which refinery effluent is discharged. The important thing to a refinery and pollution control official is the condition of the receiving waters. Waste treatment facilities must be designed to protect them.

At the six Shell Oil Company refineries wastes are collected at their sources for special handling or for destruction of harmful characteristics before release to sewers. Common illustrations of this practice are:

1. The use of area separator boxes for removal of flotable oil and settleable solids from the sewers, thereby permitting rapid measurement and rigid control of oil leakage from an area.
2. Blocked-in collection systems for preventing the loss of processing chemicals such as phenols, acids, caustics, etc.
3. Collection and stripping facilities for removal of sulfides from fractionating column accumulator waters throughout a refinery.

Less common methods of preventing pollution at the source are: (a) air oxidation of sulfides, (b) flue gas treatment of spent caustics, and (c) neutralization of spent caustics. These processes are developed in the discussion.

Air Oxidation of Sulfides

Disposal of sulfide-bearing process water and caustic soda solutions is a water pollution abatement problem familiar to most refiners. This problem has been solved by the industry through the development of several treating processes, such as aeration, lagooning, chlorination, and stripping with steam or flue gas. Some of these methods are based on the disposal of the sulfur compounds into the atmosphere; for example, sulfides may be stripped from the water with flue gas or steam and discharged into the atmosphere after burning. Therefore, the solution of a water pollution abatement problem may contribute to air pollution problems in areas having inadequate natural ventilation. As a solution to these combined problems, a continuous air oxidation process has been developed which makes possible the disposal of sulfide-bearing solutions without objectionable pollution of either surface waters or the atmosphere.

This air oxidation process was developed and applied at one of Shell's refineries where both water and air pollution abatement are unusually critical. A steam stripping unit was installed several years ago to remove sulfides from the sour water obtained in the thermal and catalytic cracking processes. Hydrogen sulfide from this stripping unit was burned in nearby furnaces and resulted in light stack plumes under certain atmospheric conditions. This procedure did not violate any air pollution regulations; however, since it was felt desirable to reduce sulfur dioxide emissions to a minimum, other methods of treatment were investigated. The air oxidation proc-

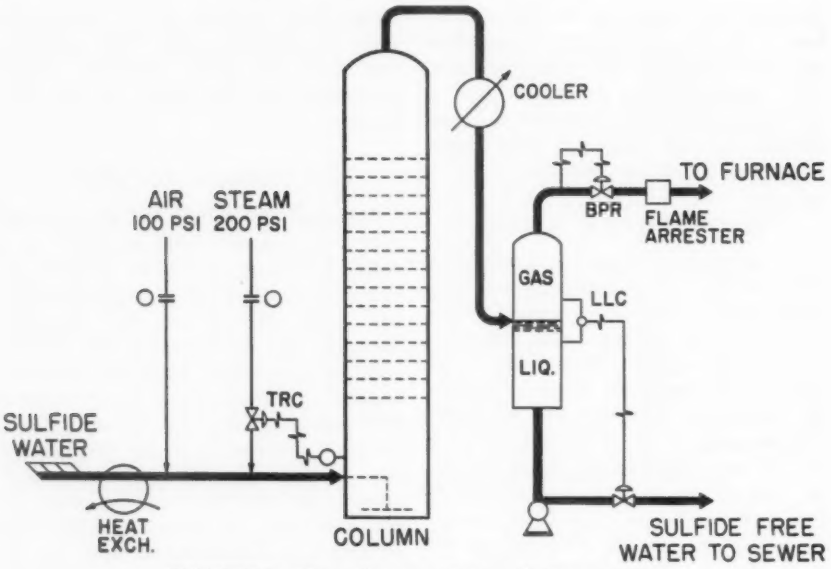

FIGURE 2.—Flow diagram of air oxidation process.

ess was developed as the result of this investigation.

The process is based on the conversion of the obnoxious sulfides to the less objectionable thiosulfates, with air, at elevated temperatures and pressures. The thiosulfates are water soluble and are retained in the refinery effluent water. Thiosulfates are not objectionable in most refinery effluents.

The principal reaction involved in the oxidation process is:

$$2S^{=} + 2O_2 + H_2O \rightarrow S_2O_3^{=} + 2OH^{-}$$

The theoretical oxygen requirement in the above reaction is approximately 1 lb for each pound of sulfide; on this basis, oxidation of one ton of sulfur each day would require approximately 80 std cfm of air. However, in the actual operation of plant units it has been necessary to use somewhat more than the theoretical amount of air.

A simplified flow diagram (Figure 2) shows the essential features of the air oxidation process. The sulfide water is preheated to about 160° F by exchange with hot residue. Preheating is an economy measure and is not required before the introduction of air. Compressed air is then injected into the water and followed by sufficient steam to reach the desired reaction temperature. Introduction of air before steam prevents the usual hammering from rapid condensation of steam. Air flow is hand-controlled and temperature is regulated by a recorder controller on the steam flow lines. Water and air enter the bottom of the column through a special distributor and both phases flow upward out of the column through a cooler and into the gas-liquid separator. Sulfide-free water is then drained from the separator to the sewer through a valve regulated by a liquid-level controller.

The exhaust gas is discharged through a back-pressure regulator into the firebox of a nearby furnace. Although the gas is normally free of hydrogen sulfide, it does contain a small amount of ammonia and hydrocarbons.

A flame arrestor is provided in the waste gas line to the furnace. Although the exhaust gas is not explosive, it is possible that explosive conditions

TABLE I.—Summary of Physical and Operational Data of Air Oxidation Waste Treatment Units at Shell Oil Co. Refineries

Unit Number	1	2	3
Source of water	Cracking units	Crude unit	C_3-C_4 treaters
Sulfide concentration (ppm)	7,000	700	50,000
Feed rate (bbl/day)	3,000	600	300
Sulfide oxidized (tons/day)	3.5	0.07	2.7
Cation type	NH_4^+	NH_4^+ and Na^+	Na^+
Temperature (° F)	200	150	250
Pressure (top) (psig)	60	10	35
Air rate*	600	20	350
Air rate†	210	130	150
Oxidation column:			
Height (ft)	35	57.5	57.5
Diameter (ft)	6	3	3.5
Internals	14 grid trays	30-ft of Raschig rings	30 bubble cap trays
Tray spacing (in.)	18	—	18

* Cubic feet per minute at standard conditions.
† Per cent of theoretical.

can occur during abnormal operating conditions. As an additional safety precaution steam is injected into the waste gas line to the furnace.

Three air oxidation units are now in operation at one of the Shell Oil Company refineries. These units process solutions which have a wide range of sulfide concentrations. Pertinent data on these units are summarized in Table I.

Flue Gas Treatment of Spent Caustics

A flue gas carbonator has been in service fourteen months charging a

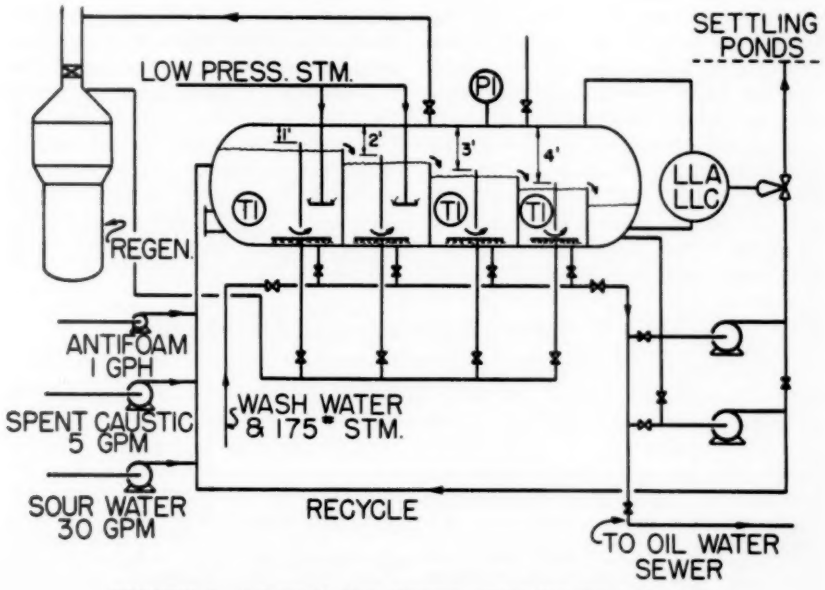

FIGURE 3.—Schematic flow diagram of the flue gas carbonator.

mixture of 4 gpm of spent caustic and 30 gpm of sulfide water. The combined neutralizing and stripping action of the catalytic cracker regenerator flue gas on this mixture has resulted in average sulfide, mercaptan, and phenol removals of 98, 97, and 70 per cent, respectively (Figure 3).

The major piece of this unit's equipment is the 10-ft diameter by 40-ft long horizontal carbonator vessel, divided internally by cross-sectional weir plates into five compartments. The first four of these compartments contain flue gas distributors and cross-sectional baffles to provide intimate contact between liquid and gas. The fifth, or outfall compartment, acts only as a surge to provide for level control. Each compartment is also provided with clean out and steam out connections. Waste steam heaters are provided in the first two compartments to augment heat from the flue gas for maintenance of liquid temperature at 200° F. Flue gas distributors in the bottom of the compartments are longitudinal 8-in. pipes with two parallel rows of ¼-in. holes on the undersides. This arrangement provides continuous flue gas sweeping of the bottom to prevent catalyst accumulation.

Mixed spent caustic from the treatment of volatile hydrocarbons, gasolines, and distillates is charged to the carbonator vessel at atmospheric temperature with sour water from the catalytic cracker main fractionator accumulator. The four cross-sectional weir plates provide four stepdowns in liquid level and a retention time of approximately seven hours. The arrangement of weirs and baffles prevents channeling of liquid through the carbonator and also provides for more disengaging space in the compartments where maximum acid oil stripping is taking place. The treated waste liquid containing cracking catalyst and carbonates is pumped from the carbonator to a series of earthen ponds, where, in combination with other waste streams containing solids, a settling period of approximately 20 days is obtained.

Flue gas is taken from the catalytic cracker regenerator at a rate of 140,000 cu ft per hour and conducted to the four distributors in the carbonator. This gas containing approximately 9 per cent carbon dioxide reaches the spent caustic sour water mixture in the carbonator at 700° F and 10 psig. The flue gas bubbles through the liquid where carbon dioxide forms carbonic acid which neutralizes the caustic and springs hydrogen sulfide and acid oils. The acid oils are stripped from the aqueous solution by the high volume of flue gas. Water condensation from flue gas and steam entering the vessel is approximately in balance with vaporization of water from the vessel. Used flue gas carrying hydrogen sulfide, mercaptans, and acid oils returns from the carbonator through an insulated line to a point near the top of the stack. Typical properties of the flue gas carbonator charge are summarized in Table II.

TABLE II.—Properties of the Charge to Flue Gas Carbonator

Charge	Charge Rate	Temp. (° F)	Gas Constituents—Per Cent Molecular Weight					Aqueous Charge Contaminants (ppm)		
			CO_2	CO	O_2	H_2O	N_2	Sulfides	Mercaptons	Phenols
Flue gas	140,000 cfm	700	10.0	10.0	0.6	16.0	63.4	—	—	—
Spent caustic	4 gpm	85	—	—	—	—	—	3,200	3,300	10,000
Sour water	30 gpm	85	—	—	—	—	—	900	16	400

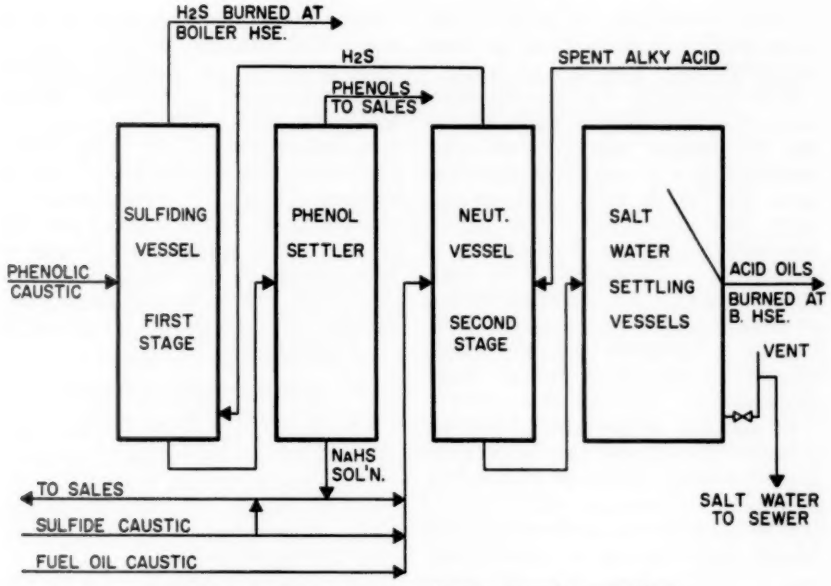

FIGURE 4.—Flow diagram of spent caustic neutralizer.

Although waste caustics with high phenol contents have caused foaming on several occasions, antifoam injection at a rate of 10 ppm has proved effective. Results from the operation of this unit have proven to be as good, or better in some respects, than was expected.

Neutralization of Spent Caustics *

At one of Shell's refineries it is necessary to dispose of some 500 to 700 bbl per day of spent caustic soda solutions containing a few per cent mercaptan sulfur, up to 20 per cent by weight of sulfide sulfur, up to 20 per cent by volume of phenols and thiophenols and having a gravity of 15° to 20° Bé. These caustics are disposed of by neutralization. A simplified flow diagram of the equipment is depicted in Figure 4.

Phenols are removed by springing with an excess of hydrogen sulfide in the first stage. The acid oils released in this stage are sold. The resulting sodium acid sulfate is then acidified with sulfuric acid in the second stage, which causes evolution of the hydrogen sulfide. This neutralization with strong sulfuric acid raises the liquid temperature to 180° to 200° F and provides the only heat needed for the process. The hydrogen sulfide is piped at about 20 psi pressure to the previous stage for springing the phenols, and the excess is piped to a boiler house for burning. The boiler is equipped with a stack 225 ft high. Experience has shown that spent caustic containing sulfides should be neutralized separately from the sulfide caustics to reduce formation of elemental sulfur.

The salt water from the acidification flows to settling tanks where acid oils, not removed in the phenol stripping, are skimmed from the top. The settled salt water is then drained to the sewer.

The sulfiding vessel and phenol settler are from 6 to 8 ft in diameter and are lined with lead. The neutralizing vessel is 8 ft in diameter and

* U. S. Patent No. 2,367,172. Royalty free rights are made available to use this process, but only for waste disposal purposes.

is lined with monel. The three salt-water settling vessels are 750-bbl tanks lined with lead. Piping is of monel.

It is imperative for the successful removal of the phenols and acid oils that the caustic charge to the neutralizer have a gravity of not less than about 15° Bé in order that the salt water will be saturated with sodium acid sulfate to reduce the solubility of phenols to a minimum. Very little phenols can be removed by acidification of weak caustics, and should this be attempted, excessive pollution would result from drainage of the salt water to the sewer.

In addition to the 15° to 20° Bé caustics the refinery has some 2,000 to 3,000 bbl per month of 1° to 2° Bé caustics which contain about 0.5 per cent by volume of phenols and varying concentrations of sulfides and mercaptans. The caustics originate from product-treating steps requiring use of weak caustics. Little could be accomplished by acidification of these weak solutions, so concentration to about 15° Bé is done by blowing with low pressure air in open top tanks heated to about 180° F with exhaust steam. The utilities requirements for this concentration are about 8,000 cu ft of low pressure air at standard conditions and about 400 lb of exhaust steam per barrel for a total cost of about $0.10 per barrel. After concentration, this caustic is suitable for charge to the neutralizer along with the other spent caustics.

Neutralization of the caustic solutions by this patented process removes all but traces of sulfides and mercaptans and about 99 per cent of the phenolic compounds.

The disposal of these particular spent caustics has been one of the most difficult and thoroughly studied problems. Every known method of treatment and disposal has been considered, including: (a) deep well disposal, (b) chlorination, (c) chlorine dioxide treatment, (d) ozone treatment, (e) flue gas treatment, (f) incineration, (g) electrolytic oxidation, (h) solvent extraction, and (i) various combinations of these. On the basis of cost and over-all effect on the total effluent it was determined that disposal by concentration and neutralization in combination with a final effluent treater is most satisfactory.

Further Considerations

The facilities described herein and the numerous more common ones have represented a cost to Shell Oil Company of many millions of dollars. Daily operational and maintenance costs are considerable.

There are other problems not covered by the methods described. In a large refinery there are many small sources of pollution for which individual treatment or handling may not be justified; in addition, oil which has leaked to the sewers imparts a small but undesirable taste and odor to the water which is not readily removed by settling. However, there are numerous methods and combinations of methods by which these pollutants can be removed from water. All are expensive and some create other disposal problems. A detailed study of possible methods for treating these pollutants at the Wood River, Ill., refinery indicated that for such marginal sources, treatment of the combined waste water stream would be most effective. Facilities for this treatment, costing over one million dollars, are now under construction. Such facilities for treatment are already in operation at the Anacortes, Wash., refinery.

TANNERY WASTES TREATMENT WITH SEWAGE AT WILLIAMSPORT, PENNSYLVANIA *

By T. R. Haseltine

Partner, The Chester Engineers, Pittsburgh, Pa.

The Williamsport tannery of the Armour Leather Company has a capacity of 52,000 to 54,000 lb of hides per day. When operating at capacity, the plant produces about 400,000 gpd of wastes, approximately 75 per cent of which are discharged over a 10-hr period. Smaller volumes are discharged over weekends. The tannery utilizes the vegetable tanning process and maintains multiple effect evaporators in which about 10,000 gal of spent tan liquor are concentrated daily, for sale as a water conditioning agent. This represents 30 to 60 per cent of the daily discharge of tan liquors, depending upon the extent of tannery operations. Since spent tan liquor is quite acid and high in BOD, the evaporation of a portion of it materially reduces the BOD and conversely increases the alkalinity of the remaining waste. This effect is most apparent when the tannery is operating at less than capacity. At such times, the majority of the waste flow contains considerable caustic alkalinity but no bicarbonate alkalinity. However, the low weekend flows may be highly acidic as pH values as low as 2.5 have been observed in composite samples of Saturday or Sunday flows. Tables I and II contain analyses of the wastes. The data in Table I are representative of midweek, peak operation in 1947, while those in Table II are monthly averages over a year during most of which the tannery was operating considerably below capacity.

* Presented at the 1957 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; University Park, Pa.; Aug. 28–30, 1957.

Tannery Waste History

Originally, all tannery wastes were discharged directly to Lycoming Creek near its junction with the Susquehanna River. From about 1936 to 1955 the wastes were pumped to one or the other of two earthen settling basins for primary treatment by sedimentation. The two basins, each with a 3-day detention period, were operated on the fill-and-draw principle. One basin was drawn down at a uniform rate while the other was receiving the raw wastes. Sludge that accumulated in the basins was periodically withdrawn to a diked lagoon of about five acres. Initially this lagoon had a depth of 10 to 12 ft, but by 1946, it had become so full that future service appeared limited to a few years. Furthermore, the lagoon lay in the course of the flood protection levee then being designed by the U. S. Corps of Engineers. Since the Armour Leather Company had been unable to acquire any other suitable area for sludge storage, it was faced with the problem of either negotiating with the City of Williamsport for the treatment of the tannery wastes or transferring production operations to one of its other tanneries.

Municipal and Combined Waste History

At that time all municipal sewage was being discharged to the Susquehanna River without treatment, but a study was in progress to determine how sewage treatment facilities might best be provided. In April 1946 a recommendation was made that the city con-

TABLE I.—Volume and Character of Tannery Waste and Treated Effluent from Old Abandoned Armour Leather Company Treatment Works *

Item	Raw Waste as Received	Settling Basin Effluent	Sludge Lagoon Supernatant
Volume (gpd)	408,775	357,230	4,600
Color, APHA (ppm)	950	650	550
Dissolved solids:			
Volatile (ppm)	1,285	1,365	1,320
Fixed (ppm)	2,760	2,840	2,450
Total (ppm)	4,045	4,205	3,770
Suspended solids:			
Volatile (ppm)	1,710	365	115
Fixed (ppm)	453	105	45
Total (ppm)	2,163	470	160
Suspended solids (lb/day)	7,354	1,395	6
Settleable solids (ml/l)	210	1.4	0.8
pH	7.3	10.8	7.0
Alkalinity (ppm)	483	975	805
Oxygen consumed (ppm)	724	530	265
5-Day BOD (ppm)	1,325	1,030	900
5-Day BOD (lb/day)	4,505	3,360	34

* Based on 48-hr composite samplings and analyses by State Health Department in May 1947, when tannery was operating at near capacity.

struct two treatment plants, one to serve the central portion of the city and some adjoining communities (1) and the other, or West Plant, to serve that portion of the city west of Lycoming Creek. After detailed investigations, it was concluded that the West Plant could be constructed to serve the tannery also, but to do so would practically double the treatment plant's initial cost as well as its operating cost.

Since the tannery's total employment of approximately 900 persons and an annual payroll of $2 million represented a large industry in the city, there was considerable reluctance to see it close. The city council authorized the preparation of detailed plans for the West Sewage and Waste Treatment Plant, which was to be capable of treating the tannery wastes as well as the sewage from the western portion of Williamsport. The plans were approved by the state in 1948; construction was started in 1953; and the plant went into operation in December 1954. This paper deals primarily with the design and operation of the combined waste treatment plant; however, Table I shows the effectiveness of the older method of treatment.

Design Criteria

The plant was designed to handle a maximum of 500,000 gpd of industrial wastes plus the sanitary sewage from an ultimate population of 10,000 people. Since existing sewers are of the combined type, the plant was designed to handle average and maximum flows of 1.1 and 2.1 mgd, respectively. It incorporates primary treatment and chlorination with vacuum filtration and incineration of the resulting undigested sludge. Since no biological processes were involved, and in view of the high lime content of the tannery wastes, it was expected that the plant might serve as an ideal means of treating acidic metallurgical and similar industrial wastes toxic to sludge digestion though amenable to alkaline precipitation, or for the sludges resulting from other treatment of such wastes. The construction of the plant was delayed until after the two principal producers of such wastes in Williamsport had completed private

TABLE II.—Character of Wastes—Monthly Averages

Year and Month	Flow (mgd)	5-Day BOD (ppm)	pH*	Suspended Solids (ppm)	Settleable Solids (ml/l)
			(*a*) Tannery Wastes as Received		
1956					
May	0.241	659	10.7	1,920	224
June	0.238	799	11.0	1,970	215
July	0.197	688	10.9	2,115	222
Aug.	0.257	732	10.5	2,200	288
Sept.	0.240	666	10.1	2,145	253
Oct.	0.171	689	10.8	3,060	228
Nov.	0.212	533	10.5	2,140	226
Dec.	0.202	681	11.8	2,290	224
1957					
Jan.	0.185	638	10.7	2,380	235
Feb.	0.142	659	8.9	2,535	267
Mar.	0.137	709	10.7	2,630	227
Apr.	0.169	621	11.5	2,020	217
Avg	0.199	675	10.7	2,250	235
			(*b*) Municipal Sewage as Received		
1956					
May	0.382	159	6.7	166	3.9
June	0.423	146	7.0	203	5.1
July	0.415	122	6.5	142	3.1
Aug.	0.466	144	6.8	165	4.2
Sept.	0.329	101	6.7	192	4.6
Oct.	0.427	120	6.8	211	4.9
Nov.	0.421	125	6.4	84	1.5
Dec.	0.298	154	6.2	157	4.5
1957					
Jan.	0.274	157	7.0	168	3.1
Feb.	0.357	136	6.7	222	7.4
Mar.	0.459	147	6.6	157	3.0
Apr.	0.335	151	6.2	88	0.6
Avg	0.382	141	6.6	163	3.8
			(*c*) Plant Effluent		
1956					
May	0.623	181	10.5	565	29.0
June	0.661	134	10.7	472	17.3
July	0.612	178	10.8	409	14.8
Aug.	0.723	174	10.9	521	36.6
Sept.	0.569	191	10.0	1,994	1,139
Oct.	0.598	144	10.7	492	27.2
Nov.	0.633	171	11.1	606	61.5
Dec.	0.500	112	9.9	960	86.2
1957					
Jan.	0.459	119	10.8	981	71.7
Feb.	0.499	128	9.7	550	45.9
Mar.	0.596	166	9.4	1,060	81.0
Apr.	0.504	146	9.9	772	21.6
Avg	0.581	156	10.4	760	136.0

* Arithmetic average and hence of doubtful significance.

waste treatment facilities, and as a result the tannery is the only major contributor of industrial wastes at the present time.

Sewage Collection System

Although the plant is capable of handling various types of industrial wastes, the same is not true of the sewage collection system. Obviously the collection system could not receive acidic wastes. Another belief was that, if tannery wastes entered the city sewers, normal calcium carbonate might be precipitated by the reaction of the bicarbonate alkalinity of the sewage with the caustic alkalinity of the tannery wastes. It was feared that such precipitation, together with the high solids content of the tannery wastes,

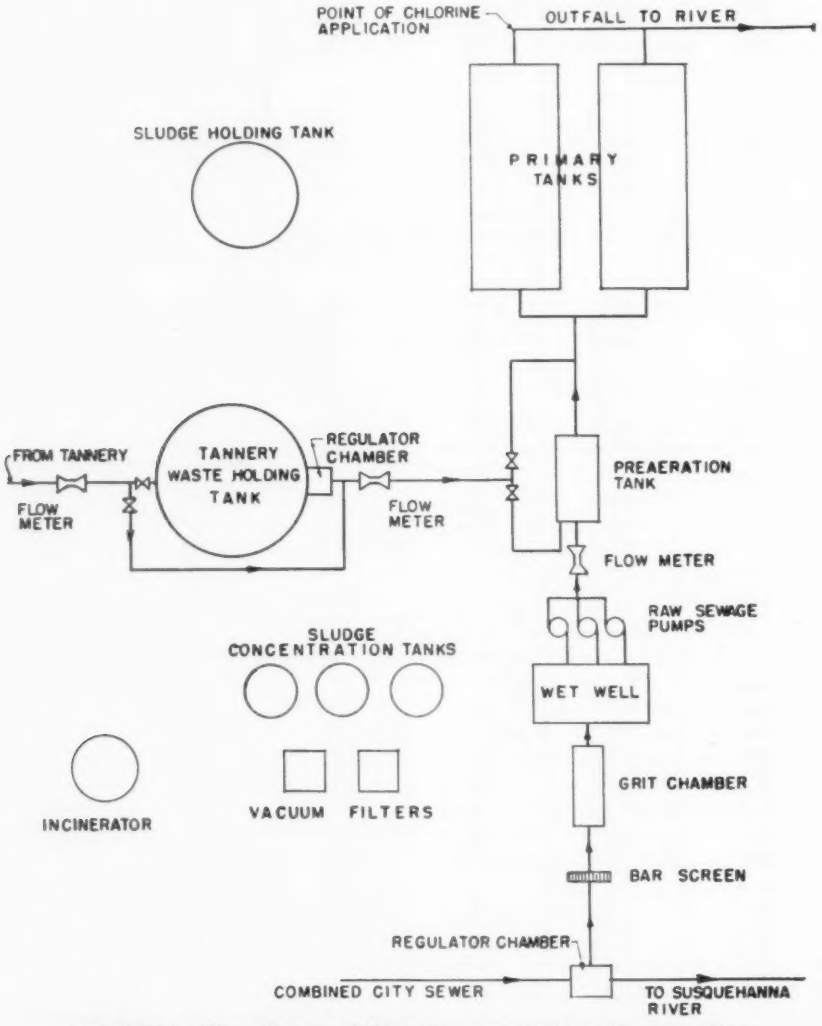

FIGURE 1.—Flow diagram of West Sewage and Waste Treatment Plant, Williamsport, Pa.

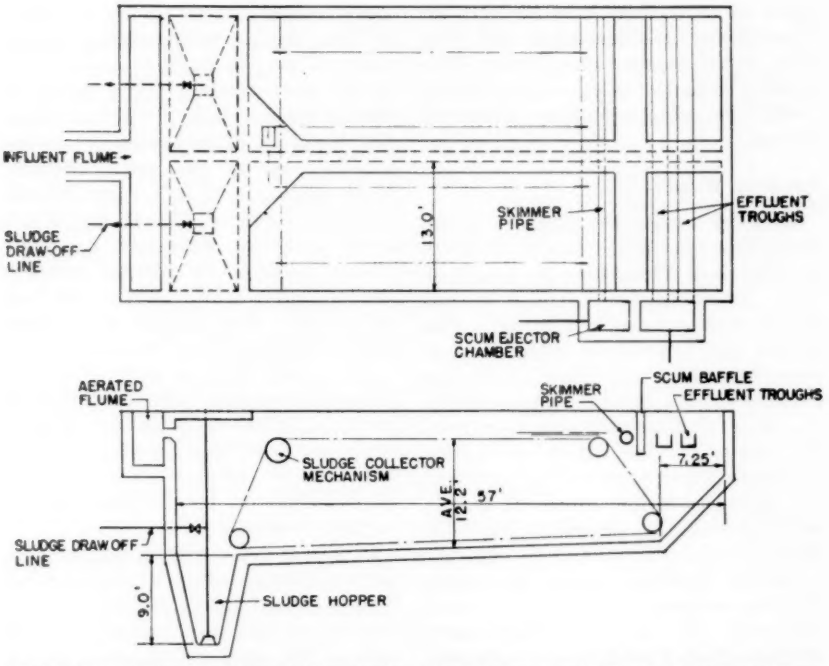

FIGURE 2.—Primary sedimentation tanks, West Sewage and Waste Treatment Plant, Williamsport, Pa.

might cause sewer clogging such as occurred in the South Essex, Mass., sewerage system (2). Therefore, the sewage and tannery wastes do not mix before reaching the plant.

Treatment Plant Description

Municipal Sewage

A flow diagram of the plant is shown in Figure 1. Municipal sewage reaches the plant through a flow regulator in a combined sewer. At the plant the sewage flows through a mechanically cleaned bar screen and a retention type grit chamber to a wet well, from which it is pumped to the preaeration tank. The grit chamber is mechanically cleaned and has a theoretical retention period of about two min at a maximum flow of 1.6 mgd. Grit and screenings are delivered to the incinerator by means of a bucket elevator and belt conveyors.

Two variable speed pumps and one constant speed pump are provided. They are of such capacity that two pumps can handle the maximum design flow, leaving one variable speed pump available for standby service. Pumps are float-controlled in such a manner that their discharge rate generally follows the rate of sewage inflow.

The preaeration tank is of the spiral flow type equipped with spargers. It has a theoretical retention period of 48 min at an average flow of 1.1 mgd. Air is supplied by either one or both of two positive displacement blowers, each of 150 cfm capacity.

There are two rectangular sedimentation basins (Figure 2) equipped with conventional chain and flight sludge collection and skimming mechanisms. Together these tanks theoretically afford a 2.7-hr retention period, a surface settling rate of 740 gpd/sq ft, and an overflow weir rate of 10,600 gpd/ft

based on an average flow of 1.1 mgd. The effluent is chlorinated and then flows to the Susquehanna River. The plant is designed to permit the future installation of a secondary treatment process.

Tannery Wastes

Tannery wastes are pumped to the plant through approximately 2,800 ft of 10-in. and 12-in. pipe by means of three quadruplicate plunger pumps taking suction from a wet well. The pumps and most of the discharge line were furnished and installed by the tannery which retains responsibility for their maintenance and operation. The pumps are float controlled in such a manner that operation is intermittent but, when operating, discharge is at a constant rate of approximately 700 gpm.

At the treatment plant the wastes enter a tannery waste holding tank which is 70 ft in diameter and equipped with a mechanical sludge collector but has no overflow weir or fixed liquor level. The tank outlet is situated to allow about 800,000 gal of liquid storage capacity above, and about 60,000 gal of sludge storage capacity below. The principal purpose of this tank is to permit the treatment of tannery wastes at a uniform rate throughout a 7-day week despite the wide fluctuations in the rates of discharge by the tannery. However, this arrangement also makes possible the collection of the heaviest tannery solids prior to further treatment. From the tannery waste-holding tank the wastes pass through a flow regulator and Venturi meter and then become mixed with the municipal sewage at either the inlet or the outlet of the preaeration tank. Separate Venturi meters are provided to measure the incoming flows of tannery wastes and municipal sewage.

Sludge Handling

Sludge is pumped from the tannery waste-holding tank and the two primary sedimentation basins by either of two duplex reciprocating pumps. Delivery may be made to any of three sludge concentration tanks or to the sludge storage tank. The concentration tanks are of steel construction and are housed in the main building. These tanks are 17 ft in diameter with a center depth of 31.5 ft and a side depth of 23 ft. Each tank has a volume of 5,910 cu ft. Sludge enters at the top and is drawn off from the conical bottom. Supernatant can be withdrawn at 2-ft vertical intervals.

The sludge-holding tank is a 40-ft diameter concrete tank, having a capacity of 26,400 cu ft. It has a floating cover and resembles a sludge digestion tank in most respects but is unheated. Supernatant can be withdrawn at 2-ft vertical intervals.

Sludge is dewatered on two coil-type vacuum filters, each of which has an effective area of 150 sq ft. Belt conveyors receive the filter cake (as well as sewage grit and screenings) and discharge to a 14-ft 3-in. diameter, 6-hearth incinerator. A pneumatic conveyor system delivers the ash to an outside storage bin from which it is periodically removed by truck.

Plant Operational History

Although the plant has received municipal sewage since December 1954, the first tannery waste was treated in June 1955. The tannery did not complete pump installations until August 1955. Since that time the plant has handled all tannery wastes despite numerous problems of both design and operation, the more important of which are described herein.

Over-all Plant Performance

Monthly operating data for the period of May 1956 to April 1957 inclusive are presented in Tables II to V. From Table II, it is apparent that the plant effluent was higher in both BOD and solids than was the incoming mu-

TABLE III.—Biochemical Oxygen Demand Data

Year and Month	Pounds per Month					Monthly Per Cent Reduction
	Tannery Waste	Municipal Sewage	Total into Plant	Effluent	Reduction	
1956						
May	40,920	15,720	56,640	29,140	27,500	48.5
June	47,400	15,450	62,850	22,200	40,650	64.7
July	35,030	13,080	48,110	28,150	19,960	41.5
Aug.	48,670	17,360	66,030	32,550	33,480	50.8
Sept.	39,900	8,310	48,210	27,150	21,060	43.6
Oct.	30,380	13,240	43,620	22,230	21,390	48.9
Nov.	28,200	14,260	42,460	27,000	15,460	36.5
Dec.	35,650	11,870	47,520	14,480	33,040	69.5
1957						
Jan.	30,380	11,130	41,510	14,110	27,400	66.0
Feb.	21,840	11,340	33,180	14,870	18,310	55.3
Mar.	25,000	19,900	44,900	25,600	19,300	57.1
Apr.	25,900	12,620	38,520	18,400	20,120	47.9
Avg	34,106	13,690	47,796	22,990	24,806	54.0

nicipal sewage. However, this was expected in view of the fact that one-third of the total flow through the plant was tannery waste. From Tables III and IV the apparent average BOD removal was 54 per cent, while the suspended solids removal was only 13.7 per cent. These reductions are in sharp contrast with the performance of the old Armour Leather Company waste treatment facilities which, as calculated from Table I, removed only 24.7 per cent of the BOD, but 81 per cent of the suspended solids. It is even more significant to compare Tables III and IV and note that during September, March, and April, more suspended solids left the plant than entered but, nevertheless, average BOD removals ranged from 43.6 to 57.1 per cent.

TABLE IV.—Suspended Solids Data

Year and Month	Pounds per Month					Monthly Per Cent Reduction
	Tannery Waste	Municipal Sewage	Total into Plant	Plant Effluent	Indicated Reduction	
1956						
May	119,820	16,430	136,250	90,830	45,420	33.2
June	116,810	21,450	138,260	78,300	59,960	43.5
July	107,500	15,190	122,690	64,480	58,210	47.5
Aug.	146,120	19,900	166,020	97,650	68,370	41.1
Sept.	129,380	15,810	145,190	283,500	−138,310	−95.1
Oct.	135,560	23,310	158,870	75,950	82,920	52.2
Nov.	113,350	8,880	122,230	95,700	26,530	21.7
Dec.	119,240	12,090	131,330	124,000	7,330	5.6
1957						
Jan.	113,780	11,900	125,680	116,560	9,120	7.2
Feb.	83,540	18,510	102,050	53,840	49,210	48.1
Mar.	90,540	18,600	109,140	163,800	−54,660	−50.1
Apr.	88,880	7,350	96,230	97,000	−770	−0.8
Avg	113,710	15,783	129,493	111,798	17,695	13.7

TABLE V.—Sludge Disposal Data

Item	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Average
(a) Concentrated Sludge to Filters													
Volume (cu ft)	13,940	11,630	6,220	21,655	23,460	20,575	12,870	121,000	16,092	15,345	15,730	7,735	14,779
Solids (%)	8.0	8.4	9.25	10.5	8.55	9.1	8.8	8.9	7.4	8.0	9.45	9.7	8.85
Volatile solids (%)	57.3	65.4	61.5	57.8	59.3	58.6	59.5	59.3	59.0	59.7	59.0	59.0	59.5
Sludge solids (lb)	69,750	61,200	35,760	141,980	126,000	116,870	70,800	67,270	74,400	76,720	93,000	46,800	81,713
Lime (%)	26.6	21.4	20.5	13.9	15.3	18.2	17.2	20.2	18.3	17.3	13.8	10.5	17.3
Ferric chloride (%)	10.2	3.6	3.7	2.2	2.7	2.7	2.8	3.4	6.1	6.3	5.6	5.6	4.25
pH before chemicals	10.9	10.3	9.8	10.2	9.3	9.1	10.3	10.5	9.7	11.4	11.1	10.5	10.3
pH after chemicals	11.9	11.8	11.6	11.6	11.7	11.7	11.7	11.6	11.7	11.8	11.7	11.7	11.7
(b) Filter Cake to Incinerator													
Total weight (lb)	342,380	249,960	148,820	475,140	362,540	399,640	220,640	254,940	280,520	271,920	328,900	167,300	291,900
Solids (%)	20.8	20.5	21.0	21.8	19.8	20.2	18.1	19.6	18.6	20.5	20.8	21.5	20.0
Volatile solids (%)	47.0	54.0	53.5	48.9	52.0	51.5	52.2	53.3	54.3	55.0	58.0	54.3	52.5
Solids (lb)	71,300	51,300	31,300	103,500	71,700	80,600	39,900	49,910	52,200	55,720	58,400	36,000	58,490
(c) Vacuum Filter Operation													
Total filter operation (hr)	531.0	413.0	225.5	573.5	540.5	604.0	406.0	468.5	523.0	542.0	580.0	267.5	472.9
Loading (lb/sq ft/hr)*	0.88	0.99	1.06	1.65	1.55	1.86	1.17	0.96	0.95	0.95	1.07	1.17	1.15
Solids recovery (%)*	102.1	83.8	87.8	73.0	56.9	69.0	56.4	74.2	71.1	70.1	62.9	77.0	71.6
(d) Incinerator Operation													
Days idle	4	8	16	4	6	4	12	9	6	4	5	17	8.0
Days heating up	4	4	5	4	5	4	3	4	5	4	5	2	4.1
Days burning	23	18	9	23	19	23	15	18	20	20	21	11	18.3
Oil/day, heating (gal)	140	147	129	148	151	116	157	123	145	139	128	140	138
Oil/day, burning (gal)	117	117	130	153	144	163	148	158	163	163	149	152	147
Cake charged/burning day (ton)	7.425	6.950	8.250	10.325	9.250	8.675	7.325	7.075	7.013	6.798	7.775	7.600	7.975
Oil used/ton cake while burning (gal) †	15.8	16.8	15.8	14.8	15.5	17.8	20.2	22.3	23.2	24.0	19.2	20.0	18.4
Solids charged/burning day (lb)	3,090	2,950	3,480	4,500	3,770	3,500	2,660	2,780	2,610	2,786	2,820	3,270	3,180
Oil used/1,000 lb moisture evap. (gal) †	9.9	11.1	9.9	9.5	9.4	10.8	12.3	13.85	14.25	15.05	11.55	12.8	12.5

* These figures include no allowance for sludge conditioning chemicals.
† Exclusive of oil used on days when incinerator was being heated up.

Operating Theories

It is believed that this strange phenomenon is the result of one or more chemical reactions between sewage, tannery waste, and filtrate from vacuum filters. Coagulation of matter originally present in the dissolved state materially increases the total suspended solids load on the plant. Despite the fact that the plant can remove only part of these newly formed, flocculent solids, there is enough removal to effect a considerably higher BOD reduction than could be expected if the reactions did not take place. This reasoning is supported by the fact that although the analyses of plant influents and effluent (Tables II and IV) indicate an average monthly suspended solids removal of only 17,695 lb, the

TABLE VI.—Examples of Effect of Vacuum Filter Operation on Performance of Sedimentation Basins

Item	Operational Period		
	June 7–8, 19, July 2–6, 12–13, 16, 18–20, 23–24	June 11–15, 25–29, July 25–27, 30–31, Aug. 1–3	Sept. 11–14, 17–21, 24–28
Number of days included	16	18	14
Basin influent:			
mgd	0.615	0.545	0.490
5-Day BOD (ppm)	350	487	507
pH	10.62	11.26	11.08
Suspended solids (ppm)	860	1,060	1,110
Settleable solids (ml/l)	54.0	68.4	82.0
Basin effluent:			
5-Day BOD (ppm)	182	173	215
pH	10.58	11.17	11.05
Suspended solids (ppm)	456	480	2,680
Settleable solids (ml/l)	2.0	18.3	242.0
Per cent removals by basins:			
5-Day BOD	48.0	64.5	57.7
Suspended solids	47.0	54.7	−141.5
Settleable solids	96.3	73.2	−195.0
Sludge to filters:			
Cubic feet per day	0	802	1,170
Solids (%)	—	9.15	9.7
Volatile solids (%)	—	62.7	60.5
Sludge solids (lb/day)	0	4,570	7,090
Lime (%)	—	18.2	14.5
Ferric chloride (%)	—	3.0	2.7
pH before chemicals	—	10.0	9.4
pH after chemicals	—	11.7	11.8
Filter cake to incinerator:			
Total pounds per day	0	18,420	19,500
Solids (%)	—	20.8	19.6
Volatile solids (%)	—	54.7	52.5
Solids (lb/day)	0	3,830	3,820
Vacuum Filter Operation:			
Filter (hr/day)	0	25.0	27.2
Loading (lb/sq ft/hr) *	—	1.22	1.73
Solids recovery (%) *	—	83.8	54.0

* These figures include no allowance for sludge conditioning chemicals.

sludge analyses (Table V), indicate that an average of 81,713 lb of solids were applied to the filters, and 58,490 lb of solids were fed to the incinerator monthly.

One of these coagulation reactions is undoubtedly the previously mentioned precipitation of normal carbonate resulting from the mixing of the caustic alkalinity of the tannery wastes with the bicarbonate alkalinity of the sewage. Another is believed to be a reaction between ferric salts remaining in the filtrate and the tannery wastes. There may also be other more complicated coagulation phenomena.

The filters could not be operated several days during the summer of 1956 due to remodeling of the ash conveyor system. Table VI compares the effluent obtained during those days with that of intervening days when the filters were in operation and also with that of the last three weeks in September, when the plant effluent was particularly high in solids. Since the filters were not normally operated on Saturdays and Sundays, those days have been excluded from the comparison. During the periods shown in Table VI, both tannery wastes and sewage were being aerated ahead of the primary sedimentation basins; therefore representative samples of the mixed wastes could be obtained from the outlet of the preaeration tanks, *i.e.*, the influent to the sedimentation basins. The table indicates that, even when the filters were not in operation, BOD removals were considerably higher than could be obtained by plain sedimentation of tannery wastes alone, thus indicating the importance of the reactions between tannery wastes and sewage. It seems probable that had there been sufficient sewage to convert more of the hydroxide to carbonate, still better BOD reductions might have been obtained. Although the suspended and settleable solids removals were not as good as might be expected from plain sedimentation of tannery wastes, they were considerably better than those obtained when the filters were operating.

Until recently all filtrate from the vacuum filters has been returned to the wet well ahead of the raw sewage pumps. It is apparent from Table VI that this practice further improves BOD removal, but materially increases the settleable solids content of the plant effluent. Naturally some solids pass through the filters and are returned to the plant. The amount of solids so recycled probably depends upon the effectiveness of the chemical treatment of the sludge ahead of filtration. It is believed that the recycled solids are difficult to settle out and so may account for some of the increased solids content of the plant effluent. However, even during the poor solids recovery period of late September, the BOD removal was still higher than it would have been if the filtrate were not recycled.

Although the high settleable solids content of the effluent represents very little of its BOD it does detract from its appearance. Better clarification is desirable if it can be obtained at reasonable cost. Obviously improvement could be provided by building additional and larger sedimentation basins at great expense.

Experimental Operation

During the fall of 1956 an experimental two week period of operation included the addition of spent steel mill pickle liquor to the preaeration tanks and to the inlet of the sedimentation basins. However, the results failed to show any significant improvement in either solids removal or sludge filterability.

Recently the filtrate has been temporarily diverted to the tannery waste-holding tank. The objective is to retain the advantage of the coagulating effect while affording more time for the newly formed and recycled solids to settle.

Preaeration Problems

A previous statement was that tannery wastes, upon leaving the tannery waste holding tank, could join the municipal sewage either ahead of, or beyond, the preaeration tank. Until October 1956, the tannery wastes joined the sewage ahead of the aeration tank. This procedure was followed in the belief that the resulting prolonged mixing would favor reactions between the tannery waste, sewage, and the filtrate. However, persistent calcium carbonate clogging of the spargers necessitated taking the tank out of service for cleaning every 2 or 3 weeks. Doubling the air input by operating both blowers, instead of only one, did not improve the situation. An investigation revealed that the clogging was due to a build-up of calcium carbonate around the sparger orifices. Since October, the tannery wastes have joined the sewage beyond the aeration tank. As a result no clogging has been encountered and the aeration tank has not required cleaning in eight months. From Tables III and IV it may be computed that average BOD and suspended solids removals prior to October 1 were 49.8 and 14.1 per cent, respectively, while after that date the removals were 54.4 and 12.0 per cent, respectively. Thus, it appears that preaeration of the mixed wastes was of no real advantage. It is believed that the substitution of carbon dioxide for air might have yielded still better results. Some consideration was given to blowing incinerator stack gas into the mixed waste through the spargers; however, the necessity for cooling those gases before handling by the existing blowers discouraged actual experimentation.

Sludge Problems

By far the most serious problem has been the concentration and filtration of the sludge. Initial operation of the filters showed that in order to be successful the applied sludge should contain at least 6 to 7 per cent solids, although higher solids concentrations were preferable. The original design anticipated that sludge would be pumped daily from the sedimentation basins and the tannery waste holding tank to one of the three sludge concentration tanks. After quiescent standing for 24 to 48 hr, the supernatant would be withdrawn and the remaining sludge sent to the filters. This procedure yielded an unsatisfactory sludge containing only 4 to 6 per cent solids. The addition of 1 per cent ferric chloride (on a solids basis) to the sludge as it entered the concentration tank, appeared to assist in thickening but the benefit was not considered sufficient to warrant the added cost. A trial of single-stage elutriation of the concentrated sludge was made by transferring bottom sludge from one concentration tank to another tank partially filled with well water. However, the sludge failed to regain its original concentration upon prolonged standing. Laboratory attempts to concentrate the sludge by aeration and flotation also were unsuccessful. Finally a procedure was developed that usually yields a sludge containing from 8 to 10 per cent solids. That procedure is as follows:

1. Sludge is pumped from the sedimentation basins to the sludge holding tank only 2 to 5 times a week at a rate of about 60 gpm.
2. Sludge is pumped from the tannery waste holding tank to the sludge holding tank only 1 to 3 times a week at the same rate.
3. All possible supernatant is decanted from the sludge holding tank daily.
4. Periodically, sludge is transferred from the bottom of the sludge holding tank to one of the concentration tanks and allowed to stand at least 24 hr. Additional supernatant forms and is decanted.
5. The remaining sludge is either transferred to a second concentration

TABLE VII.—Sludge Disposal Operations and Costs During Selected Periods

Period	A	B	C	D	E
Number of days included	1	4	6	6	9
Sludge to filters:					
Cubic feet per day	1,537	838	735	586	672
Solids (%)	9.2	10.5	8.0	7.9	9.3
Volatile solids (%)	55.0	50.1	53.5	54.3	61.0
Sludge solids (lb/day)	8,820	5,510	3,678	2,898	3,910
Lime (%)	10.85	10.7	20.1	19.4	12.4
Ferric chloride (%)	6.67	5.82	5.15	0	5.1
Copperas (%)	0	0	0	12.7	—
pH before chemicals	11.6	11.45	11.11	11.19	10.93
pH after chemicals	11.3	11.48	11.84	12.17	11.53
Filter cake to incinerator:					
Total pounds per day	34,600	18,930	14,000	11,300	15,127
Solids (%)	22.6	22.7	19.8	20.1	20.6
Volatile solids (%)	51.7	51.5	55.1	49.3	56.0
Solids (lb/day)	7,800	4,293	2,775	2,271	3,120
Vacuum filter operation:					
Filter operation (hr/day)	25.7	18.9	23.0	21.2	26.3
Loading (psf/hr) *	2.29	1.95	1.07	0.91	0.99
Solids recovery (%) *	89.0	78.0	75.4	78.5	79.7
Incinerator operation:					
Oil used (gal/day)	145	176	208	178	153
Oil used (gal/ton of filter cake)	8.3	18.6	29.7	31.5	20.1
Oil used (gal/1,000 lb moisture evaporated)	5.4	12.0	18.5	19.6	12.7
Chemical & fuel costs per 100 lb solids applied to filters ($):					
Lime @ $0.02/lb	0.217	0.214	0.402	0.384	0.248
Ferric chloride @ $0.08/lb	0.534	0.466	0.412	0.000	0.408
Copperas @ $0.03/lb	0.000	0.000	0.000	0.381	0.000
Oil @ $0.165/gal	0.271	0.526	0.933	1.015	0.646
Total	1.022	1.206	1.747	1.780	1.302

* These figures include no allowance for sludge conditioning chemicals.

tank or recirculated in the same tank and then permitted to stand quiescent for at least 24 hr. Additional supernatant is decanted. The remaining sludge is then delivered to the vacuum filters.

It was originally hoped that, because of the high lime content of the tannery wastes, the sludge could be conditioned with ferric chloride alone. However, it has been found necessary to use sufficient lime to bring the ferric chloride treated sludge back to a pH of at least 11.0. Extensive laboratory and plant-scale tests have been conducted to improve filter rates and reduce chemical costs. The chemicals which can be used are, in the order of their effectiveness, ferric chloride and lime, copperas and lime, lime alone, and sulfuric acid and alum. Several proprietary compounds as well as activated carbon, sawdust, incinerator ash, and lime fly ash have been tried but none appeared to be of significant value.

Table V shows monthly averages for the filters and indicates that, over the entire year, only 1.15 psf/hr of sludge solids were handled with lime

and ferric chloride dosages of 17.3 and 4.25 per cent, respectively.

Table VII shows similar data for four earlier periods and one recent period. Period A represents the day the incinerator was tested, July 21, 1955. On that day engineers and chemists representing the designers and equipment manufacturers made a concentrated effort to obtain maximum cake production with the minimum of moisture. During all other periods shown the plant personnel were in full charge of operations.

During Period B, August 8–11, 1955, the sludge applied to the filters was unusually high in solids and, as indicated, considerably better performance was obtained than with the more dilute sludge during Period C.

Period C includes October 12, 13 and 17–20, 1955, while Period D includes October 21 and 24–28 of the same year. The concentrated sludge was quite similar in character during both of these periods. Ferric chloride and lime were used during period C and copperas and lime during D. During C, 5.15 per cent ferric chloride, or 1.78 per cent iron, was used, while during period D, 12.7 per cent copperas, or 2.54 per cent iron, was used. About 17 per cent more solids were handled during period C, indicating that in this comparison the ferric chloride was of more value.

The last period, E, May 13–17 and May 21–24, 1957, is included to permit comparison of typical recent performances with the earlier periods.

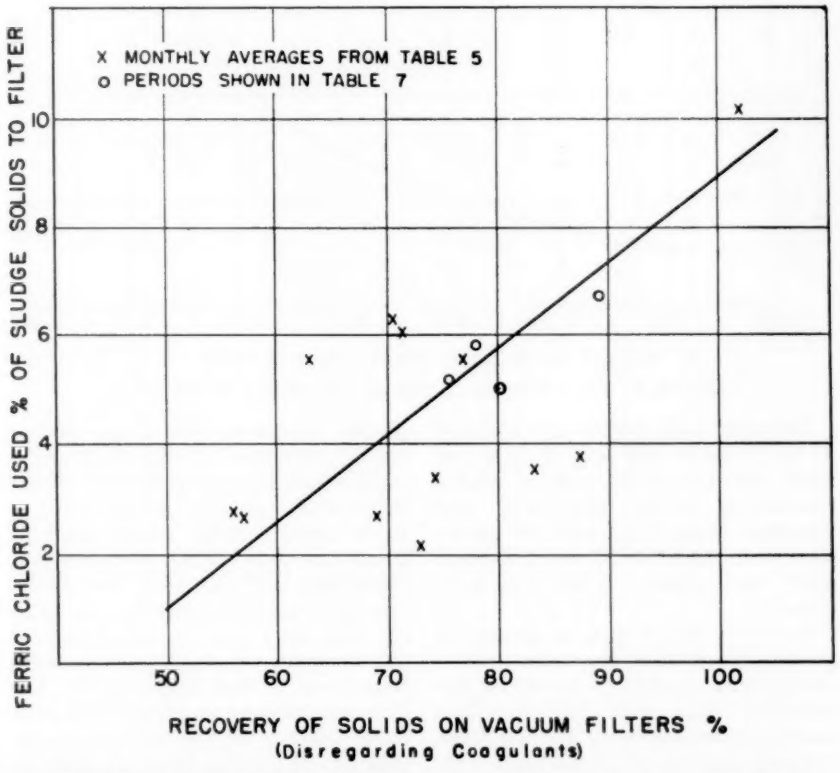

FIGURE 3.—Effect of ferric chloride dosage on solids recovery by vacuum filters.

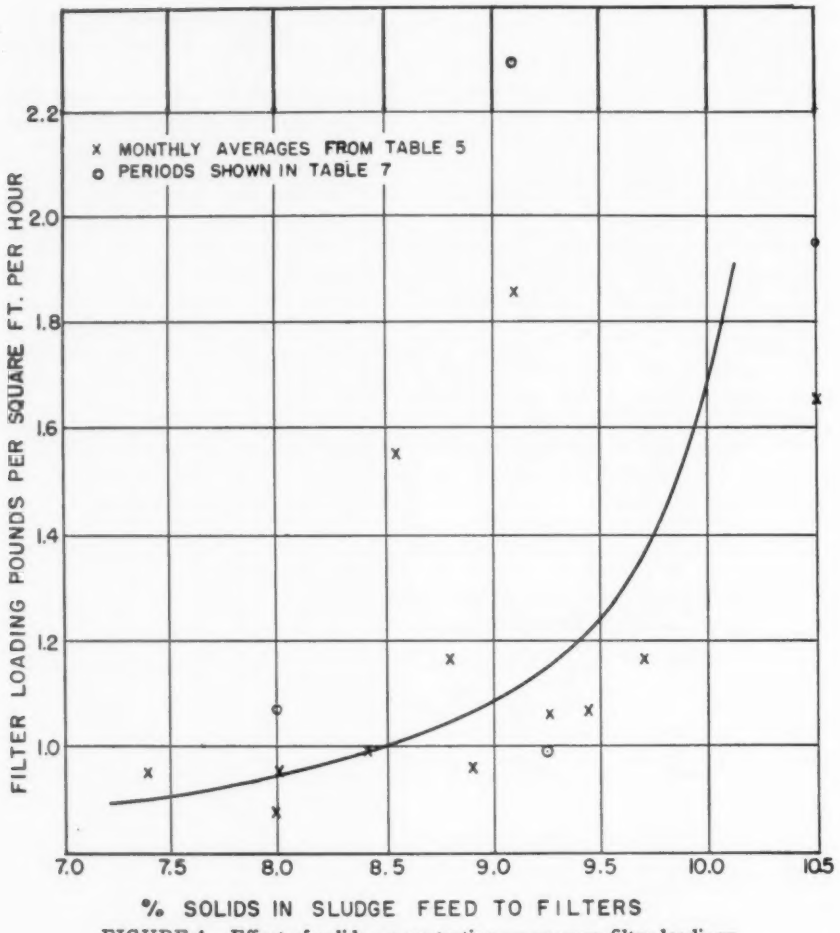

FIGURE 4.—Effect of solids concentration on vacuum filter loadings.

Normally both filters are operated 11 to 14 hours per day, 5 days per week, but frequently lack of sludge necessitates longer shutdowns and therefore production is not as important as it would be if the treatment plant was operating nearer its peak capacity.

Table V indicates that, on the annual average, only 71.6 per cent of the sludge solids applied to the filters are recovered and that corresponding monthly averages have ranged from 56.9 per cent to 102.2 per cent. In Figure 3, these percentages have been plotted against the percentage of ferric chloride used. Although there is considerable scattering, it appears that better solids recovery would result if more ferric chloride were used. In subsequent tests (Table VIII) it was found that, although more ferric chloride improved solids recovery, the filter rate was not improved and the actual cost of sludge disposal was increased. Experience to date indicates that the filter rate is more dependent upon the solids content of the applied sludge than on the amount of ferric chloride used (Figure 4).

The original filtrate pumps were self-priming centrifugals and were the source of a great deal of trouble due to clogging with hair from the tannery wastes. The filter manufacturer replaced these with diaphragm pumps at no cost to the Authority. Operation has now been uninterrupted for something over 15 months without clogging. Only one of the two diaphragms has required replacement. Although these pumps are extremely satisfactory, they are not recommended for operation against the 50-ft head required to deliver filtrate to the tannery waste-holding tank. Hence routine discharge of filtrate to that tank must await installation of additional, or different, pumping equipment.

Incinerator Operation

The incinerator operation has not been troublesome; however, the poor yield of high moisture filter cake has materially increased oil consumption over that originally contemplated. The specifications required that the performance of the furnace be based on approximately 14 hours of operation plus 10 hours of standby. Guarantees were to be based on filter cake containing only 70 per cent moisture. Since the filters could not produce such a dry cake, it was necessary to com-

TABLE VIII.—Comparison of Various Ferric Chloride Dosages

Item	June 11–14, 1957	June 17–21 and 24–28, 1957	July 1–5 and 8–12, 1957
Number of days included	4	10	10
Sludge to filters:			
Cubic feet per day	570	802	1,105
Solids (%)	8.1	7.2	7.15
Volatile solids (%)	61.1	61.5	63.5
Sludge solids (lb/day)	3,400	3,610	4,880
Lime (%)	12.4	12.5	13.3
Ferric chloride (%)	5.6	8.9	12.0
pH before chemicals	11.18	10.99	10.69
pH after chemicals	11.80	11.52	11.20
Filter cake to incinerator:			
Total pounds per day	12,930	16,940	21,052
Solids (%)	19.1	20.4	19.4
Volatile solids (%)	58.1	59.7	60.8
Solids (lb/day)	2,470	3,460	4,080
Vacuum filter operation:			
Filter (hr/day)	17.1	23.6	27.4
Loading (lb/sq ft/hr) *	1.33	1.02	1.19
Solids recovery (%) *	72.7	95.7	83.8
Incinerator operation:			
Oil used (gal/day)	142	156	162
Oil used (gal/ton of filter cake)	22.0	18.4	15.4
Oil used (gal/1,000 lb moisture evaporated)	13.6	11.6	9.6
Chemical & fuel costs per 100 lb solids applied to filters ($):			
Lime @ $0.02/lb	0.248	0.250	0.266
Ferric chloride @ $0.08/lb	0.448	0.712	0.960
Oil @ $0.165/gal	0.689	0.713	0.547
Total	1.385	1.675	1.773

* These figures include no allowance for sludge conditioning chemicals.

TABLE IX.—Incinerator Test Data

Conditions of Incineration	As Assumed in Guarantee	Average During 13.5 Hr Test	Average During Test Hr of Max Load
Moisture in filter cake (%)	70.0	76.9	77.1
Solids in filter cake (%)	30.0	23.1	22.9
Heat value of dry solids (Btu/lb)	5,500	5,264	5,264*
Temp. of exhaust gas (°F)	1,200	552	550
Filter cake to furnace (lb/hr)	4,000	2,300	3,140
Moisture to furnace (lb/hr)	2,800	1,770	2,410
Dry solids to furnace (lb/hr)	1,200	530	730
Oil to furnace (gal/hr)	5.0	8.37	17.0
Heat to furnace from dry solids (Btu/hr)	6,600,000	2,789,920	3,841,720
Heat to furnace from oil (Btu/hr)	750,000	1,255,500	2,550,000
Total heat to furnace (Btu/hr)	7,350,000	4,045,420	6,391,720
Heat added per lb of moisture evaporated	2,625.0	2,285.5	2,651.8
Power used per hour of incineration (kwhr)	4.25	3.36	2.50
Power used per hour of standby time (kwhr)	2.25	1.9	—
Oil used per hour of standby time (gal)	1.5†	2.38	—

* Assumed same as average for entire test but may have been lower due to lower volatile content of sludge during this hour.

† This guarantee applied to furnace smaller than actually installed. Since volume of furnace installed is more than twice that of the small unit, this amount might be doubled.

pare actual and guaranteed performances on the basis of heat added per pound of moisture evaporated, rather than on the quantity of cake and oil consumed. The official acceptance test was made on July 21, 1955. Table IX compares the guaranteed performance with that obtained during the test period. Despite the fact that exhaust gas temperatures were materially lower during the test than had been anticipated in the guarantee, the incinerator operated without significant odor or smoke and has continued this performance.

Table V contains data on average monthly loadings and oil consumption. Normally the incinerator is fired on Sundays so that it will be ready to operate Monday morning. Usually it is charged with filter cake for 11 to 14 hr per day for five consecutive days, but there are many weeks when it is charged for only 3 or 4 days. Burners are extinguished after the last charge is burned. There have been occasions when, due to lack of sludge, the incinerator was idle for a week or more. Table V shows that, on the average, almost as much oil is required to bring the incinerator up to temperature as is required to burn the daily charge. Therefore, it is apparent that fuel consumption could be reduced by starting the incinerator less frequently and operating it for longer continuous periods. This has not been done because of the difficulty of adjusting the operator's hours to such a schedule.

In Figure 5 the oil used per ton of filter cake is plotted against the tons of cake charged to the incinerator daily. The figure contains no adjustment for variations in moisture content, volatile content, or heat value of the filter cake. It is believed that most of the oil is used to evaporate the cake moisture; therefore, in Figure 6, the volume of oil used per 1,000 lb of moisture is plotted against the daily charge of dry solids. Again no adjustment has been made for the volatile content or heat value of those solids. Both curves include the oil burned during the 10 to 13 hr of idle time between daily charging periods, but not the oil used initially to bring the incinerator up to temperature after it has been down for longer periods. The inflection point on the curve in Figure 5 is at about 7.6

tons per day. Based on 20 per cent solids, this would be equal to a solids charge of about 3,000 lb per day, and this is in good agreement with Figure 6, which has its inflection point at about 2,900 lb. From a study of these figures it becomes apparent that the incinerator would be far more efficient if vacuum filter rates could be improved to provide an increase in the charge. It appears that, for about half the time, the charge has been so light that extremely high fuel consumption could not be avoided.

Early in 1956 some trouble was encountered with the breaking of the cast iron blades on the top rabble arms. Corrosion appeared to be a major factor. At the same time it was noted that the wet sludge tended to ball up and cling to the blades, rather than to move across the hearth as intended. The incinerator manufacturer corrected the situation by substituting longer blades of a special alloy iron.

In sharp contrast with the incinerator proper, the pneumatic ash handling equipment was the source of considerable trouble until the answers to handling the high lime content ash were found. At times the counterweighted gates between the cyclone separators and the ash storage bin failed to close, thus causing loss of vacuum and failure to move ash. At other times the gates failed to open, thus permitting ash to be drawn back through the return lines and wet vacuum pump, with resulting clogging. For almost a year many unsuccessful schemes were tried. Finally, it was decided to abandon the counterweighted

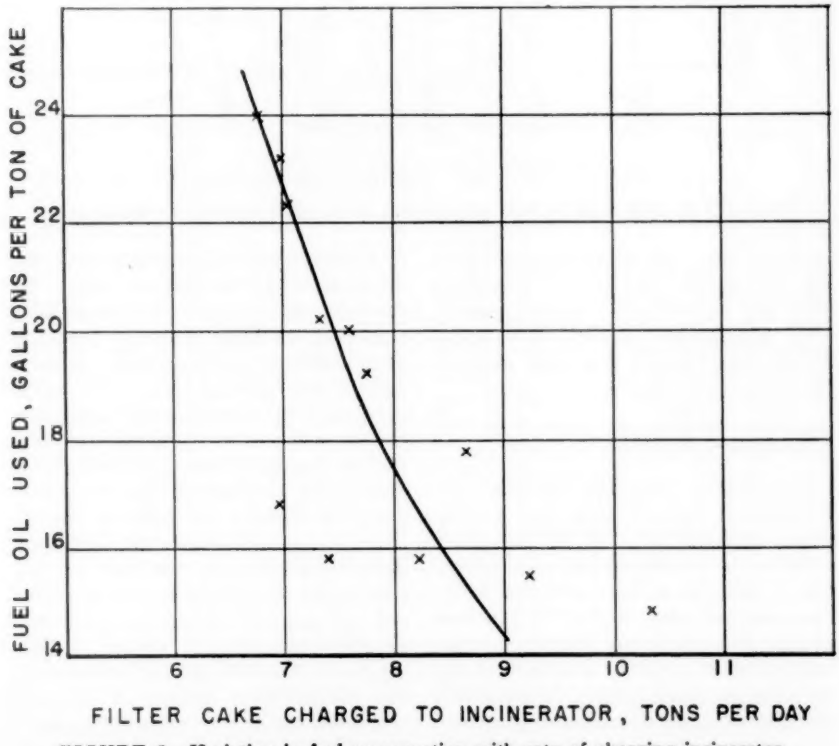

FIGURE 5.—Variation in fuel consumption with rate of charging incinerator.

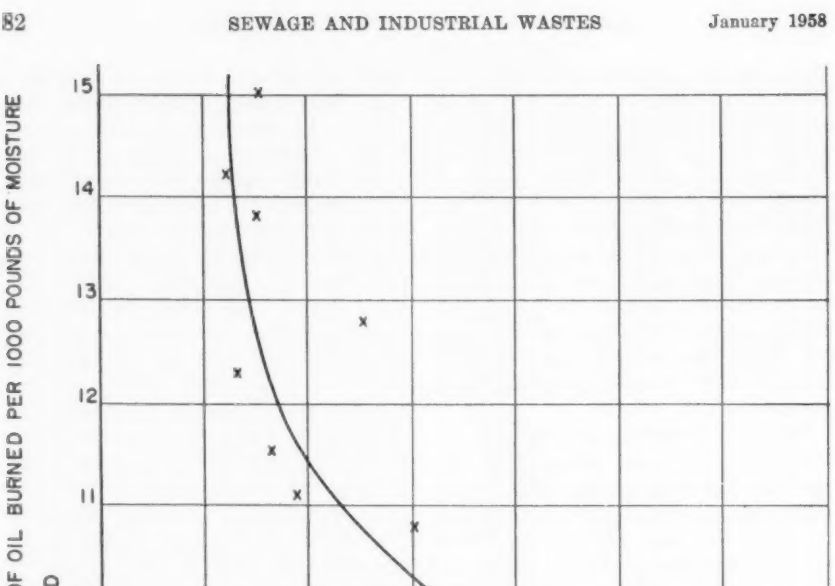

FIGURE 6.—Variation in fuel consumption with solids loading on incinerator.

gates entirely. Hydraulically operated gates, utilizing oil as the operating fluid and controlled by electric timers, were substituted during July 1956. No further trouble has been encountered since the change.

Chlorination Facilities

Chlorination facilities include two chlorinators each of which has a maximum capacity of 400 lb per day. Chlorine is purchased in ton containers. Piping is so arranged that chlorine solution may be fed to the raw sewage wet well, the tannery waste holding tank, and the discharge from the sedimentation basins. Until about the first of 1957 it was normal procedure to feed 40 to 100 lb of chlorine to the tannery waste-holding tank and 20 to 60 lb to the effluent daily. No residual was carried in the holding tank and the high color and turbidity of the effluent made it difficult to be certain of a residual there. The original reason for chlorinating the holding tank was to control odors but odor control at that point has proved unnecessary. The tank smells like a tannery and is so close to the tannery that its odor is unobjectionable to local residents. Chlorination of the tannery wastes was continued, however, to control the maggots which otherwise were prolific during warm weather. During the winter of 1956–57 chlorination was discontinued because of the serious corrosion of the steel in the center feed well during the protracted pe-

riods between the intermittent operation of the tannery pumps. (Had the tannery pumped its wastes at a continuous though variable rate, as originally contemplated, instead of at the highly intermittent rate finally adopted, this problem would not have developed.) The holding tank was bypassed during most of March and April of 1957 to permit repairs to the feed well. During that time the sedimentation basins were subjected to highly variable rates of flow. This probably accounts for the abnormally poor solids reductions by sedimentation for those months, as indicated in Table IV. During the next season it is planned to spray the surface of the liquid in the holding tank with a commercial orthodichlorobenzene product as required to control maggots.

Acknowledgments

Appreciation is expressed for the cooperation of the Williamsport Sanitary Authority and particularly that of John S. Hendershot, Superintendent both of this treatment plant and the Central Plant, Frank Heller, Secretary of the Williamsport Sanitary Authority, and Kenneth A. Glenz, until recently local representative of the Municipal Management Company which manages the affairs of the Authority as well as those of the Williamsport Water Authority.

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DISCUSSION

By Frank E. Heller

Secretary, Williamsport Sanitary Authority

Economic Considerations

As Haseltine has shown, many of the technical phases of the treatment of tannery wastes in conjunction with sanitary sewage at Williamsport are unusual. There are also unusual economic considerations that affect the rates charged to Armour Leather Company for the treatment of its wastes. These considerations influence not only the operating costs of the Williamsport tannery but also the economic life of the City of Williamsport.

The economic considerations at Williamsport, as they now exist with respect to the tannery, were not planned in advance by the City of Williamsport or the Williamsport Sanitary Authority, which constructed and is now operating the plant just described. Rather the situation was the result of a combination of circumstances.

The evolution of events leading to the construction of the West Sewage and Waste Treatment Plant for combined treatment of tannery wastes and domestic sewage has been described in part by Haseltine. Pertinent information other than that already described is included herein to complete the historical background.

Additional History

As a result of the study it was estimated that the cost of the west plant would be $588,000 if only sanitary sewage was treated, or $1,040,000 if the tannery wastes were included. The difference of $452,000 represents the initial investment required to provide treatment for the tannery waste.

The report also indicated that the additional annual debt service and operating cost for the treatment of tannery waste over that for treatment of sanitary sewage alone would be $49,550.

The fact that the site of the existing sludge lagoon, owned by the Armour Leather Company, was required for the site of a levee to be provided as a part of a $15 million flood control program then under construction by the U. S. Corps of Engineers for the City of Williamsport had considerable bearing upon the decision of the city to enter into an agreement with the tannery for the treatment of its waste.

The agreement provided that when the city constructed plants to treat its sanitary wastes the designs would incorporate provisions for the treatment of tannery wastes as well. It was further agreed that the Armour Leather Company would pay an annual charge of $25,000 for treatment of its tannery wastes. Such payment, although only half of the estimated annual cost, was acceptable to the city to forestall the possibility that the tannery operations might be transferred to one of the company's other plants.

In 1951 the city was informed by the Pennsylvania Sanitary Water Board that the year-to-year permit, under which it was discharging untreated sewage to the river, would not be renewed. Plans had already been prepared by the consultants under authorization from the city and paid for with funds advanced by the Commonwealth of Pennsylvania and the Federal Government. Because of the urgency to provide relief for the overloaded lagoon of the Armour Leather Company as well as the necessity of losing the lagoon site for levee construction, the Williamsport Sanitary Authority lost no time in proceeding with the project. While contracts were being advertised for bids, counsel for the Authority advised that it could not assume the contract previously made between the city and the Armour Leather Company because it appeared that the fee to be paid by the tannery would be inequitable when compared with the charges anticipated for other users of the sewage treatment facilities.

During a series of conferences among the tannery, the Williamsport Sanitary Authority, its counsel, and the consultants, Armour Leather Company stated that any annual charge in excess of $25,000 might make its Williamsport operation so uneconomical that operations would be transferred to the company's recently closed North Bend tannery. The Williamsport Sanitary Authority, aware of the economic consequences to the City of Williamsport in the event that the $2 million payroll of the tannery was lost, and also cognizant of the necessity of imposing an industrial rate charge that would not be considered discriminatory, authorized the consultant to develop a schedule of rates for industrial waste which would provide for the treatment of tannery waste at the lowest charge defendable in court, such rates to be based on a liquid flow of 500,000 gal per day of tannery waste, with a suspended solids content not in excess of 9,500 lb per day over any consecutive 5-day period.

The regular rate schedule finally adopted by the Authority is based on water usage or volume of wastes discharged and applies to all wastes that do not contain suspended solids in excess of 300 ppm. It provides for a surcharge for wastes containing suspended solids in excess of that amount, the surcharge so imposed varying according to the amount of the excess. The schedule of rates also provides for a 30 per cent discount on the volume charge to any industry which delivers its waste directly to the sewage treatment plant as compared with those using the public sewage collection system.

Using this schedule, an agreement

was made on April 27, 1953, between the Williamsport Sanitary Authority and the Armour Leather Company, which on the basis of peak operation of the tannery would result in an annual payment of approximately $39,000 by the leather company to the Authority. A feature of this agreement called for a quarterly minimum payment by the tannery of $3,206 for a period of 20 years, unless the plant was destroyed by fire or an act of God and was not reconstructed. In the latter event the guaranteed payments were limited to 10 years. In return for offering such guarantees the tannery was granted a 15 per cent discount on the regular adopted schedule of rates.

Operating Costs

Williamsport's two sewage treatment plants now have been in operation for a period of 2½ years, thus permitting some comparison of actual costs and revenues with those estimated in 1948. As is frequently the case, actual costs have been found to be slightly higher and the revenues slightly less than the 1948 estimates. The reduction in revenue is due largely to the fact that during the past year the Williamsport tannery has been operating considerably below capacity. Actual operating costs for the west plant during the last half of 1956 were as follows:

Labor	$17,681.90
Chemicals	2,881.80
Fuel oil	3,605.68
Water	1,503.70
Power	3,747.75
Ash disposal	37.69
Other supplies and expense	985.63
Maintenance of structures	68.56
Maintenance of equipment	875.65
Total	$31,388.36

Conclusion

While most of the citizens of Williamsport are unaware of the economic problems considered by the Sanitary Authority and the Armour Leather Company during the negotiation of the aforementioned agreement, the members of the Board of the Williamsport Sanitary Authority were gratified when recently it was learned that the tannery had again been considering seriously closing the Williamsport plant, but had abandoned the idea because of the 80 guaranteed quarterly payments stipulated in the agreement. Thus, a $2 million payroll and employment of some 700 to 800 people has been retained for Williamsport.

RESEARCH FELLOWSHIPS

Research fellowships in sanitation are available at Rutgers University, New Brunswick, N. J., leading to M.Sc. and Ph.D. degrees in the fields of water, sewage and industrial waste treatment, stream pollution, and air pollution. Bacteriologists, biochemists, biologists, chemists, engineers (chemical, civil, mechanical, sanitary), microbiologists, and public health majors who are citizens of the U. S. or Canada are eligible. Appointments are on a 12-month basis with one month vacation. The stipend ranges from $1,800 to $2,400 plus 12 tuition-free credit hours per semester. Research may be used for advanced degree. For applications and further information address: Dr. H. Heukelekian, Chairman, Department of Sanitation, Rutgers University, New Brunswick, N. J.

Stream Pollution

POLLUTION CONTROL IN NEW ENGLAND*

By William S. Wise

Director, State Water Resources Commission, Hartford, Conn.

"When mankind runs out of water, that is the end of the road" is a warning that should be heeded by every community from the largest city to the smallest hamlet. Mankind need not find itself, at least in the foreseeable future, in such an ominous plight, but this should serve as a forceful and constant reminder that water is our most vital natural resource. It is fundamental that community welfare, growth, development and progress are strangled without ample supplies of clean water.

The drought, from which New England is just emerging, or the floods of 1955, with their disastrous consequences, should convince everyone that our water problems are growing more severe and complex.

There are two powerful influences involved in the correction of these conditions: natural forces, which frequently are responsible for rainfall in amounts that are either excessive or inadequate; and human nature, which frequently causes variations in attitudes from extreme enthusiasm to utter complacency. These are opposing forces—natural forces cause a challenge to the initiative of the alert and the industrious, while all too preponderant a segment of human nature allows apathy to inhibit constructive activity. Of these two forces, it is more difficult to deal with human nature.

For centuries our clean waters have been abundant, but through selfishness they have deteriorated—through complacency and apathy they are being wasted and their utility greatly impaired.

Water Resources Development and Pollution Control

Water

Water resources serve humanity in multifarious ways apart from any other natural resource. To satisfy the rapidly growing demands our water resources must be developed to meet the whole gamut of uses—from vital water supplies to the recreational, aesthetic and other beneficial applications.

Many problems would be simplified if rainfall were distributed uniformly throughout the year at the rate of about 3.5 in. per month or 0.9 in. per week. At one station in Hartford there were 9.5 in. of rainfall in two days in 1955 and less than 0.5 in. in 40 days during the past summer; however even these conditions do not represent the extremes. Then, too, the demand for water in some areas is tremendously greater than it is in other areas. Furthermore, in New England there are groups concentrating on water for domestic supplies, industrial process use, recreational purposes, sewage and industrial wastes disposal, power, agricultural crop irrigation, and for its many aestheic values. Thus, there are active interests in water for a great variety of uses requiring various degrees of quality, purity, and

* Presented at 30th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Boston, Mass.; Oct. 7–10, 1957.

quantity. The demands for water are obviously growing much more rapidly than are the corrective and constructive programs necessary for providing a more abundant clean water for everyone's requirements. A clean river and abundant water supply are the greatest assets of any community or any industry.

In New England the water problem has not been approached as a whole and in an integrated manner. The planning has been piecemeal and there has been little effort to appreciate the water needs. There has been proper recognition of the school, health, industrial, and other community needs but not of the water requirements, and yet there are practical methods available for solution of all the water problems.

Pollution Control

Stream pollution control is the easiest and the most practical method of augmenting the water resources to meet the various needs. This is the only practical way of meeting some of the important requirements of the changing social and economic life. The construction of more and larger reservoirs involves extensive areas of land which are placed under rigid restrictions as to use and development. This is not only costly but is becoming more difficult. Ground water in unlimited amounts is very rare. Weather control is not now feasible. De-salting of sea water may be practical, but can serve only those areas located near the coast line. All these methods are laden with definite limitations. The combined task of cleaning up the streams and intelligently using their resources to meet the many needs of this country is the most practical and economical method. Quite importantly it is the most equitable solution and an integral part of water resources development. Under the present status of scientific development of sewage and industrial wastes treatment, there is no justification for the discharge of any untreated sewage or industrial waste into any public waterway to the discomfort or the detriment and damage to adjacent or downstream riparian property owners. Such continued practice serves to rob the people as a whole of the full use and enjoyment of this resource.

The stream pollution control program has lagged for a number of reasons:

1. Pollution control projects are not glamorous.
2. There is a common feeling of unconcern in New England relative to a real water shortage crisis in the foreseeable future.
3. Further apathy is created by the knowledge that an unlimited water supply is available by merely flipping a faucet. In addition, the water bill is less than the telephone bill or the electric bill, and is a fraction of the gasoline bill.
4. The allocation of public funds for pollution control usually receives less attention than the powerfully supported school programs and other municipal needs.
5. Although physical expansion in industry is prevalent, there is a reluctance on the part of industry to approve expenditures for pollution control facilities.
6. Human idiosyncrasies are largely responsible for the tendencies to limit the expenditure of funds to items which result in direct returns in personal satisfaction, profit or social prestige.

It is most encouraging to note, however, the recent trend of public support for water resources development and pollution control. A recent popular magazine article described the rejuvenation of Bloomington, Ind., from a sad, decaying, water-starved community to a city now enjoying a phenomenal growth and the rebirth of a vitalized spirit, through the development of abundant clean water for domestic, industrial, and recreational use.

Articles, appearing in popular magazines and indicating a growing public interest in these vital matters, are gratifying to the dedicated workers for clean streams.

The Growing Interstate Problems

Many problems which plague intrastate agencies become more involved when interstate regions are affected. The airways and super-highways create changing conditions in communities and regional areas, thereby placing greater emphasis on the need for regional planning for all community problems.

Obviously, all streams and rivers are essential to industrial and economic growth and development, but the large rivers, interstate and intrastate, are the life blood of the region they serve. The streams become a source of indispensable electric power, supply the demands of large water users, and serve as the final receiver of the used water from their tributary areas. These rivers must be considered and protected as the most vital natural asset of any inhabited area.

The utilization of atomic energy and nuclear materials for potentially enormous beneficial use introduces complex factors in the maintenance of the rivers. The by-products of the production and use of these fissionable materials, usually discharged to the waterways in accompaniment with large volumes of water, are not amenable to natural purification processes as are organic and inorganic materials. The concentration of these materials in aquatic growths is a matter of no small concern. It is most fortunate that research in the treatment and handling of these wastes is being carried on simultaneously with the development of the products. This is in contrast to the policy of many industries of developing new products without considering the waste disposal aspects.

There can be no controversy over the fact that the rapidly changing conditions in the social, economic, industrial, commercial, and recreational life demand constant concern over the various interstate problems, not the least of which involves the complete utilization of interstate waterways.

New England Interstate Water Pollution Control Commission

Background and Organization

New England is blessed with many beautiful clean rivers, but it is also troubled with the fact that its cities, towns, and industries are much more closely huddled together in river valleys than is true in many other sections of the country. Such conditions intensify the problem of maintaining the streams in high quality condition.

As the individual states endeavored to carry out programs for cleaning up the rivers and streams, it became more and more apparent that an interstate coordinated program was essential to a sound and equitable solution. After some years of discussion and planning the New England Interstate Water Pollution Control Commission was created in 1947 when the legislatures of the States of Connecticut, Massachusetts, and Rhode Island ratified a compact which was in turn approved by Congress. In 1949 New York ratified the compact because of Lake Champlain and other interstate waters common with the New England area. Vermont and New Hampshire joined in 1951, and Maine became a member in 1955.

The area embraced by the compact is 65,000 sq miles, including a population of 9.5 million people. It is one of the most highly developed industrial areas in the Western Hemisphere, containing over 24,000 manufacturing plants. It contains about 3,500 sq miles of water surface, with 75,000 miles of rivers and streams, and has a coastline of approximately 4,600 miles. There are about 800 communities representing a population of over 6.5 million discharging untreated sewage into the waters of

the area. Nearly 850 manufacturing plants, with a population equivalent BOD load of approximately 5 million, use the public waterways for disposing of untreated wastes.

The Commission is composed of five members from each state, including the directors of the pollution control agencies in the respective states. An important part of the Commission organization is the technical advisory board, composed of the respective technical heads of the pollution control agencies of each state. This board carries out all the technical phases of the program and makes recommendations to the Commission for its consideration and action. The Commission is financed by annual appropriations from the respective states.

Comprehensive pollution control laws were adopted by the several states at various times during the past generation; however, certain phases of pollution control measures were being practiced by most states long before the establishment of comprehensive programs. Rhode Island passed its law in 1920; Connecticut in 1925; Massachusetts in 1945; New Hampshire in 1947; New York and Vermont in 1949; and Maine in 1953. The laws of each differ materially. In New York and Vermont state boards are empowered to establish classifications of the waters. In New Hampshire and Maine classification is a function of the legislature only. Classification is not authorized in the laws of Connecticut, Rhode Island and Massachusetts; however, in all three states the classification system of the New England Interstate Water Pollution Control Commission is employed.

The role of the New England Interstate Water Pollution Control Commission is to promote, formulate and carry out a sound and integrated program for the complete utilization of the interstate rivers through the authorities of the respective state agencies. The states are obligated to carry out the program within their boundaries in order to comply with the recommendations of the Commission.

Stream Classification

The compact endeavors to set up a reasonable balance of conflicting water uses in accordance with a system of classification of the rivers based on recommended highest use.

The classification plan places the river into four classes and defines each class according to (a) suitability for use, and (b) standards of quality. The description of each is shown in Table I. The standards of quality for each use are indicated in more general terms and in less detail than they are in some other states. This was necessary in order to make the plan more completely applicable to conditions in the different states without conflict with the respective laws and policies.

The studies leading to the classification of any river usually cover a period of about two years. These studies, carried on cooperatively by the affected state agencies, include the preparation of data necessary to indicate (a) the present classification based upon the existing condition of the various reaches of the river, and (b) the future classification based on improvements accruing from a sound and effective pollution control program involving both municipalities and industries. After adoption of the classification the affected states then proceed with an aggressive program necessary for raising the water quality to its potential highest use.

Research

Another important phase of the Commission's program concerns the research projects which it sponsors. These projects involve the various aspects of industrial wastes treatment common to the compact area. The studies and laboratory work are conducted at Wesleyan University, Mid-

TABLE I.—New England Interstate Water Pollution Control Commission—Tentative Plan for Classification of Waters *

Criterion	Class A	Class B	Class C	Class D
		SUITABILITY FOR USE †		
	Suitable for any water use. Character uniformly excellent	Suitable for bathing and recreation, irrigation and agricultural uses; good fish habitat; good aesthetic value. Acceptable for public water supply with filtration and disinfection	Suitable for recreational boating, irrigation of crops not used for consumption without cooking; habitat for wildlife and common food and game fishes indigenous to the region	Suitable for transportation of sewage and industrial wastes without nuisance, and for power, navigation and other industrial uses
		STANDARDS OF QUALITY ‡		
Dissolved oxygen	Not less than 75 per cent saturation	Not less than 75 per cent saturation	Not less than 5 ppm	Present at all times
Oil and grease	None	No appreciable amount	Not objectionable	Not objectionable
Odor, scum, floating solids, or debris	None	None	None	Not objectionable
Sludge deposits	None	None	None	Not objectionable
Color and turbidity	None	Not objectionable	Not objectionable	Not objectionable
Phenols or other taste producing substances	None	None	None	
Substances potentially toxic	None	None	Not in toxic concentrations or combinations	Not in toxic concentrations or combinations
Free acids or alkalies	None	None	None	Not in objectionable amounts
Coliform bacteria	Within limits approved by State Department of Health for uses involved. Sea waters used for the taking of market shellfish shall not have a median coliform content in excess of 70 per 100 ml	Bacterial content of bathing waters shall meet limits approved by State Department of Health and acceptability will depend on sanitary survey		

* As revised and accepted December 8, 1950. Waters not meeting the classification criteria of Classes A, B, C, and D are considered as unsatisfactory and as Class E.

† For purpose of distinction as to use, waters used or proposed for public water supply shall be so designated.

‡ These standards do not apply to conditions brought about by natural causes.

dletown, Conn., and at the University of Rhode Island, Kingston, R. I.

To date eleven reports have been prepared, five of which have been published for distribution (1)(2)(3)(4)(5)(6)(7)(8)(9)(10)(11). The report dealing with process and process chemical changes in wool scouring and finishing mills has attracted the greatest interest (10). The studies leading to this report sought to emphasize the need for starting pollution abatement within the factory by the utilization of process improvements and changes. In wool scouring and finishing mills it was found that the waste BOD could be reduced by as much as 95 per cent by the substitution of chemicals and detergents having a low BOD for the commonly used chemicals and soaps having a high BOD. In many instances this process change might eliminate the need for industrial waste treatment. A further benefit is the resulting substantial reduction of the volume of water used for rinsing operations by the use of modern detergents. This study demonstrates the value of a logical procedure in attacking pollution problems.

The following studies are presently sponsored by the Commission and financed partially by federal funds under grants from Public Law 660, 84th Congress:

1. Design, operation, and efficiency of textile waste treatment plants.
2. Lagooning of textile wastes.
3. A study of the characteristics of tannery wastes.
4. Study of waste treatment in areas where process chemical substitution may not be feasible.
5. Design and construction of a pilot treatment plant for wastes from small dairies.
6. Design and application of automatic controls in waste treatment.

The data, information, and treatment processes being obtained through these research projects are valuable aids, not only to the Commission but to the respective states in advancing the coordinated program.

The record of accomplishments by interstate water pollution control commissions throughout the country is proof of their fertile position and fruitful achievements in one of the country's very real and challenging problems. No doubt one of the reasons for such success is the fact that commission members live in the midst of the conditions requiring correction and become the direct beneficiaries of the endeavors. The solutions are tailored to fit specific requirements and are not based on idealistic premises, which are formulated, promoted, and executed by someone foreign to the needs and customs of the region. The New England Interstate Water Pollution Control Commission is one of these agencies dedicated to the principle of clean streams for everyone.

Pollution Control a Perpetual Problem

Pollution control in New England has a number of things in common with other regions of the country:

1. The conditions which create the problem are not static and never will be as long as this country remains a democracy where human enterprise can function.
2. The idiosyncrasies of the New England people in respect to the expenditure of funds for works of this type are no different from those elsewhere.
3. The eternal question of "How clean should a stream be?" is haunting both the proponents and the opponents with little likelihood of even a plausible answer.
4. Pollution control is a major factor in water resources development and conservation and must be administered in a coordinated and integrated program.

5. River valley policies are the most logical and equitable approach to sound water resource development.

6. Stream classifications and standards of quality will have to be revised periodically to meet constantly changing conditions.

7. Municipalities and industries must join in a united front to advance the cause.

8. Pollution control should be viewed and administered in a manner similar to other important movements (highway, health, education, etc.)—not as a discouraging never ending burden, but as a vital portion of the foundation upon which future growth, progress, and welfare always will rest.

Unfortunately, in the past, a great many people felt this to be a problem for "George" to do, but as has been proven, "George" always had so many other jobs that some had to be neglected. Pollution abatement is in the latter category. However, progress has reached a point where pollution can no longer be placed in the delayed category. Everyone, including civic groups, service clubs, women's organizations, state, interstate agencies, federal agencies, and educational institutions, must now make a contribution toward the solution of this problem.

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THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

SMALL PLANT SAFETY HAZARDS *

BY FRANK SHORT

Superintendent, Sanitation and Water Department, Lockheed Air Terminal, Inc., Palmdale, Calif.

The sewage treatment plant at Lockheed Air Terminal, Inc. (LAT), USAF Plant 42, Palmdale, Calif., is a small 3-mgd system serving all manufacturers of jet military aircraft located in one Federal Government-owned area. Here, as in other small plants where staff and facilities are limited, the operator has unusual responsibilities in the matter of ensuring personnel of safe operating conditions. Normally the small plant operator does not have available the services of a person trained to see the danger inherent in small-plant operation. Furthermore, the special hazards which exist in a small plant are not common to the experience of most safety engineers. So it becomes the responsibility of the operator to make a special study of the conditions which are present in his plant in an effort to secure the maximum degree of safety in operation. Each item of equipment and every square foot of the plant should be studied with a view to determining if any condition exists which might lead to a preventable accident.

A case in point is a circular stair well in the plant at LAT. It has a spiral guard rail along its entire length and is considered to be reasonably safe. To be completely safe, however, it should also have a 4-in. or 6-in. metal guard on the floor around the railing to preclude the possibility that a wrench or other item be kicked over the edge by a passing person to strike someone else who might be working in or passing through the well lower down.

The same stair well leads from the ground level, where the pump motors are located, to a dry well which is about 15 ft below ground level. Bearings about midway along the long drive shaft presented a lubrication problem. It was solved by connecting copper tubing to the grease fittings and running it to a central point where it is both convenient and safe to use a grease gun. Since this eliminates the need for the use of ladders to do a job, it is cited as an example of how a labor-saving device is often one that also offers greater safety in operating practice.

One of the greatest hazards to safety that the small plant operator has to contend with is that he is often working alone for extended periods of time. To minimize the danger, it is established practice at LAT to require men working alone to telephone some central control point at hourly intervals. In the event that this call is not made on schedule, the receiving operator has instructions to attempt to call the man and, if he fails to make

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

contact, to institute a search. The men working under this system have a greater sense of security than they had before it was instituted as they know that a 1-hr period is the longest they would ever have to hold out alone before help would arrive in case it were needed.

The remoteness of most small sewage treatment plants from a source of medical assistance makes it imperative that all personnel have some training in first-aid practices. Most accidents encountered in such a plant need not be serious if proper first-aid treatment is promptly administered.

In certain areas, there are special hazards in the form of black widow spiders, side winders, and scorpions. Where there is a real possibility of injury from such a source, it is advisable to have a definite plan of action for meeting this situation. Men at Lockheed are instructed (a) to apply a tourniquet, and (b) to put in a call for help immediately before shock sets in and makes it impossible to do so.

One of the greatest hazards which all sewage treatment personnel have to contend with is the danger of small wounds of such inconsequence that the individual may be inclined to feel that no treatment is necessary or justified. It is well for sewage treatment plant personnel to remember that there is a possibility that almost anything touched around a plant may be contaminated. Since it is known that typhoid is a water-borne disease, for example, all personnel working in a sewage treatment plant should have the protection afforded by shots. Advance protective treatment against the possibility of tetanus is also indicated, since danger from this source is always present and can be guarded against far better in this way than it can by treatment after infection has set in. At LAT, a record is kept of all injuries, no matter how small. In the case of small injuries, the record is destroyed after all danger of infection has passed, but it is kept available as long as there seems to be any possibility that it might be needed.

Some sewage treatment plant personnel are inclined to feel that their jobs are relatively safe and secure in comparison to many others. And so they may be. But the sewage treatment plant operator may come in contact with any germ anyone in the community may have. He works, often alone, in remote areas, climbing ladders day or night, and pulling hoses along narrow walks. He travels along narrow walks, sometimes icy, over tanks of water with submerged iron equipment. He has pits to fall into and wet wells which may contain explosive or toxic gases. His laboratories are filled with strong acids, alkalies, furnaces, fires and electrical equipment and much glass. Maybe his job is a safe one—but he will do well to be careful!

ELIMINATING SEWER MISUSE *

By Thornton Piersall

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Misuse means to subject to maltreatment or abuse. The abuse of sewerage systems is multitudinous and varied due to specific conditions or local requirements and development. The smaller cities having 20,000 to 60,000 population have a basic problem of misuse, beginning with the inception of a sanitary sewer system.

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The problem evolves customarily from poor inspection of saddle connections, a lack of preventive maintenance, improper issuance of permits for industrial waste discharge, and inadequate control after industrial waste permits are issued.

Improper Saddle Connections

Certainly one classification of misuse in Compton, Calif., was brought to view forcibly when a local utility company cut into a street to replace an underground main. A whole section of concrete pavement suddenly dropped about 4 ft below street grade and revealed an undermined section. It developed that several improper saddle connections had been made several years previously. The continual washing away of soil had excavated a cavern of immense proportions under the street. Further investigations revealed three other saddles in the immediate vicinity which were in various stages of damage.

It became quite clear that either close supervision of saddle installations would be necessary or the city would have to install them for property owners or contractors to insure proper connections. The policy was adopted requiring inspectors to be on the job at all times during the making of a saddle installation to eliminate this mistreatment of the public sewer system.

Industrial Operations

Compton is primarily a residential town; accordingly industry is varied and for the most part made up of small companies. Many of these industries were started many years ago and the facilities for properly treating or handling the sewage effluent are antiquated or improperly handled.

During a sewer cleaning operation in one particular small industrial area, an accumulation of deposited material was encountered which resembled a dense, oily, earthy metallic conglomeration practically inpenetrable by ordinary cleaning methods. A survey of the area was made by conducting a factory-to-factory inspection. It revealed that a clay pottery manufacturer was using an old elevated wooden sand and grease interceptor which had no compartments, no retention time, and was leaking profusely. Another contributor was a magnesium alloy products plant which had been discharging its material into a buried 50-gal drum which, in turn, discharged into the sewer. A plant that undercoated automobile bodies was using a room with an open floor drain. In conjunction with this undercoating, the company was using solvents, cleaning products, and soapy water which carried the asphalt coating material into the discharge line. These and various other materials were fusing to form the conglomerate which was causing the deposits in the sewer.

By requiring modification of existing facilities, installing standard design sand and grease traps, eliminating metallic sweepings from floor drains, closing other drains, and certainly by cooperation with the industries, the sewer line deposits were almost eliminated. Another factor contributing to the deposits in the sewer lines is the low volume of flow and the flat sewer grade (0.24 per cent) necessitated by the extremely flat terrain prevalent in Compton.

Wash and Storm Water

Contributing to the misuse of the sanitary sewer system has been the practice of automobile dealers of discharging quantities of uncontaminated water into the system. This occurrence was precipitated by issuance in the past of permits for car washing sumps, or open air racks which were uncovered and unprotected by a curbing to prevent surface runoff and direct flow from rain, hosing down of parking areas, and other washing activities, from flowing into the sanitary sewer system. Violators now are given

written notice that roofs and curbings are required for all wash racks, and that it is necessary that their facilities be modified to conform. Some resistance to the requirements has been experienced, but some progress is being made.

The efforts that some property owners will go to in attempting to eliminate storm water is exemplified by a modern trailer park of about 2.5 acres which had drainage problems. After completing the improvement the rain water did not drain properly, so the owner blithely constructed a grated opening and a direct drop into the sanitary sewer. This line ran through the center of the property serving the trailer spaces. The grade of the property was so nearly level that before any great buildup of surface water could occur it would flow into the sanitary sewer system. A little clever camouflage with shrubs hid this connection from discovery for a period of time. Eventually it was discovered and immediate action taken to abate this nuisance.

Cooling Water

The extensive discharge of cooling water from air-conditioning systems has been a contributing factor to the overloading of sewers. It has been classified as a misuse of the sewerage system.

One large retail store built several years ago had their air conditioning system cooling water, an uncovered ramp unloading area, and other uncontaminated waste and drainage water running to a sump which was then pumped into the sanitary sewer. In cooperation with the Los Angeles County Sanitation Districts and in keeping with its policies, the retail store was instructed to reroute the water to a storm drain. This is not an isolated case or condition; therefore, the movement to minimize the violations and misuse of the sanitary sewer system must be a continuous operation.

Control Policy

The old proverb "an ounce of prevention is worth a pound of cure" certainly applies in the prevention of misuse of the sanitary sewer system. The City of Compton has adopted a policy prevalent in other cities; that of working in cooperation with the city building department and require that building plans which indicate the probable need for control in the installation of sewer facilities must be processed through the engineering department. Applications are processed and cleared through the Industrial Wastes Division of the County Sanitation Districts of Los Angeles County.

The elimination of any sanitary sewer system misuse requires vigilant action on the part of responsible employees, periodic and routine inspection of existing facilities, analysis of acceptable standards for proposed installations, and public awareness of the problem and cost to the taxpayers.

CONSIDERATIONS IN PROMOTING THE SALE OF SEWAGE TREATMENT PLANT EFFLUENT*

By E. J. M. Berg

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Two of the fundamental rules of salesmanship are—know your customer and know your product. The manager of an industrial enterprise is the sewage treatment plant's customer for the sale of plant effluent. In many respects his work and its management are similar to those of a sewage plant

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operator; but in several very important respects it is quite different. The industry manager may be in charge of a refinery, a food processing plant, or a paper mill. These enterprises are very much different from each other, but all sewage treatment plants have fundamental similarities. Hence each prospective customer and his needs present an individual problem. There are, however, certain fundamental characteristics of operators of all industrial enterprises that differentiate them widely from sewage plant operators, and these differences shall be considered now.

The sewage plant operator never worries about the delivery of his raw material. It comes in a steady stream day after day, and all day long. His worries may be about getting too much at a time. The product to be sold, the effluent, will always be there in quantity. The industrial operator often worries about the arrival of his raw material; it is not free and the price he pays often determines whether he can compete with other operators; in fact, the raw material may be the deciding factor as to whether or not he can keep his enterprise going in the face of competition. The sewage plant operator does not compete with the operator of any other sewage plant. While his cost of operation is scrutinized when budget-time arrives, he can always truthfully say that the production of an acceptable effluent is a must, and that the cost of a law suit due to pollution, and the loss of good will due to a polluted water course, cannot be calculated in dollars and cents. His efforts and success are measured in good will and cleanliness, and neither of these has a debatable money value.

The operator of an industrial plant is constantly competing in a financial market. His success or failure can be measured accurately by the cost of production, the value of the product, and the amount of that product available for sale. His is highly competitive work. That difference between him and the sewage plant operator must be realized and properly heeded.

It is amazing what volumes of water are used in the different industries. Studies of the volumes used have been made, and these data are available in the literature. They are given as so many gallons per ton of steel produced; or ton of coal washed; or kilowatt of power generated. Two facts must be considered: the chemical and physical analysis of the water and the cost.

The analysis of the water is the first information asked for; if it is not right and must be corrected, the cost of this correction, if it is possible to correct, has a great bearing on the second factor, the cost of the water to industry. Hence the customer will first ask for the chemical and physical analysis of the effluent that is for sale. The seller must be able to talk intelligently and convincingly about his effluent; most important, what he says must be correct. He must also be sure as to what extent he can consistently and continually produce the effluent he offers. If occasional deviations occur, because there are bound to be plant upsets at times, the operator must be prepared with a remedy, not an excuse or explanation. After all, in most cases modern industry is a continuous operation.

There are various chemical and physical tests that every operator is familiar with. If he is not, if he thinks his plant is too small ever to be considered a source of industrial water, let him mend his way. Industry is expanding vastly and it is in many instances looking for a reliable source of labor, a reliable source of fuel, and a reliable supply of water. A sewage treatment plant may be able to furnish the latter. Accordingly, the treatment plant operator must be prepared to furnish data on his plant effluent. If the operator does not know how to test for nitrites and nitrates, for suspended and total solids, or any of the other substances used in determining the op-

eration of the treatment plant, he should prepare himself.

To users of cooling water the silica and phosphate content of the treatment plant effluent is important. These tests are rarely made in the sewage plant laboratory and they are not simple; they can be learned. If the operator can show the prospective customer that he is familiar with the tests and if he has the information wanted in regard to silica and phosphate, then he will make a favorable impression.

A point in connection with the analyses of the effluent is that it is not enough to be able to make and interpret these analyses; the operator must also know how to treat the effluent to decrease the unwanted constituents and increase the desired characteristics. After all, the latter is the essence of sewage plant operation.

Suppose that the effluent almost meets the specification of a possible customer; what is to be done to bring it up to these specifications? Possibly a slight change in treatment will produce the required changes. Or some structural changes in the plant may do it. Probably the changes needed will raise the cost of treatment. How much will the cost be raised, and who will pay for this?

If the change in the process improves the quality of the effluent by 10 per cent, the increase in cost will probably be more than 10 per cent, perhaps as much as 15 or 20 per cent. This is a common experience, especially if the quality of the effluent is rather high. Therefore, the operator should not let his enthusiasm carry him too far and too fast and thus make promises hard or impossible to keep.

If such additional treatment is needed, who is to bear the expense—the purchaser or the seller? Any "sharp trading" is out of place here. Both parties must profit by the arrangement, and the question as to who is to profit the most must not enter the discussion.

It is the author's philosophy that sewage treatment is a process of reconditioning objectionable used water so it may re-enter the cycle of nature and be of use to humanity. This is much more than merely making it "disposable." Remember that water is not a substance that can be wasted. The idea that it can be "expendable" is not appealing. The operator who prepares his effluent so that it may be of immediate use when it leaves his plant will have earned the gratitude of his fellow citizens.

SEWER MAINTENANCE EQUIPMENT AND ITS USE*

By Cedric Webster

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With the sole exception of the water supply, there is no utility more important or necessary to the communal health and creature comfort of man than the sewerage system. Without some means of removing the accumulated wastes, modern civilization as it exists at present could not survive for very long. The problem of disposing of his excrement is one that man has faced since time began. He has discharged his wastes into rivers and other bodies of water, he has buried them, and he has burned them. When he has failed to dispose of them he has found that he must face the inevitable

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consequence of his neglect—pestilence and disease.

The sanitary sewer is one of the simplest and most efficient methods yet devised by man for the removal of his waste products. It enables him to move large quantities of obnoxious waste material quickly, safely, effectively, and efficiently. In the United States, millions of tons of sewage are carried in these lines every day.

Like everything else, the sanitary sewer requires service and maintenance. This means manpower and equipment; equipment that has become increasingly more effective with the passage of time. One can imagine that when the Roman sewers needed attention, Julius Caesar was content to dispatch a slave or two to muck them out by hand. In Denmark in the sixteenth century, the problem of of cleaning the sewers evolved upon the local hangman, and it is safe to assume that his sewer cleaning equipment was not as efficient as his noose.

Even today in certain sections of France the sewer cleaning equipment is reported to consist of a brush fastened to the tail of a dog who is then chased through the line from manhole to manhole. It is true that some of the equipment still in use in the United States is inefficient when compared to the equipment now available.

The principal function of a sewer maintenance crew is the servicing of the various lines and appurtenances comprising the sewer system. This servicing includes not only the removal of obstructions during the actual cleaning of the lines, but the preventive maintenance act of removing incipient obstructions.

Mechanical Cleaning

Sewer Rods

No more effective piece of equipment has yet been developed to remove obstructions in a surcharged line than the steel sewer rod equipped with some sort of cutting head. When inserted into a system and rotated either by hand or machine, the sewer rod makes an effective tool. It is extremely effective in removing roots, rags, grease, and other soft material. Much of the hard physical work associated with the use of a rod can be eliminated with the rodding machine developed in recent years.

Much ingenuity has been shown in the development and manufacture of sewer rods, but much remains to be done. Improvements in quality control, steel selection, and coupling design are all urgently needed, as is the incorporation of certain safety features.

Bucket Machine

The sewer rod is an effective and efficient tool; however, it cannot be used exclusively for line cleaning. The heavy debris which finds its way into a system must be removed by other means. Equipment, such as the bucket machine, was developed for this purpose.

The cable-actuated bucket machine offers a practical method of removing large quantities of sewer debris. It is simple in design and operation, ruggedly constructed, and effective in use. Its use does not in itself create a surcharged condition, and flow in the sewer is not affected or restricted during the actual cleaning operations.

Where the governing authority is charged with maintaining the storm sewers as well as the sanitary lines, it is possible for this machine to perform a double function.

The many virtues of the bucket machine, however, do not gainsay the fact that it also has disadvantages. On small lines particularly, it is slow, and on some models the bucket has a tendency to ride over an obstruction rather than to dig in. The size and weight of the equipment generally restrict it to use on streets and do not permit use

along narrow public utility easements or in other restricted areas.

Hydraulic Cleaning

The force of impounded water can be effectively used to clean sewers. Sewer balls, cones, scooters, and flushing nozzles are all examples of hydraulic cleaning equipment. Their efficacy depends on the hydraulic principle that an increase in velocity in a moving stream is accompanied by a greatly increased ability to move entrained material. The transporting capacity of water varies as the sixth power of its velocity; doubling the velocity increases the transporting capacity sixty-four times. For example, when a sewer ball is inserted in a line where the normal velocity might be 2 fps, a partial obstruction to the flow is created and sewage backs up in the line. If the line were to back up to a depth of 4 ft the theoretical velocity of the escaping jet would be about 16 fps or eight times the normal velocity. When it is realized that water at this velocity has approximately 264,000 times the transporting capacity of water at 2 fps, the efficacy of these devices can be better appreciated.

Equipment of this type is simple to operate, fast and effective. In addition to its use on city streets, it can be used equally well in public utility easements or other restricted areas where other types of cleaning equipment might not be able to operate. As with other types of equipment, these hydraulic cleaning devices have their disadvantages. Probably the most serious shortcoming is the flooding dangers attendant upon their use. There is always the possibility that the backing up of the line may result in the flooding of homes and other buildings connected to the line, particularly when the sewer line is on hilly or sloping terrain. Another serious disadvantage is that hydraulic devices cannot be used in a surcharged line.

Chemical Cleaning

Although chemicals cannot be properly included under the generic term of equipment, their application for cleaning lines is becoming more widely used as improvements in the chemical composition are made and as the cost is reduced. One of the most commonly used chemicals consists of a strong caustic, which tends to saponify grease and oil deposits as well as to break down the complex organic compounds which may be lodged in a line. There have even been some claims that the chemicals will at least inhibit, if not burn out, root growths in the system. Such success has not been adequately proved. It is sufficient to state that these chemicals serve a purpose and a can or two may be properly placed on the maintenance truck and used on some of the more troublesome spots in any system.

Another chemical which has been used in sewer work is copper sulfate or bluestone. It has been stated that if this material is used systematically and in sufficient quantities, root growth in sewers can be controlled, if not inhibited. Chemical root control has not been particularly successful in California. This may be partially attributable to the semi-arid climate and to the indestructibility of the California eucalyptus tree.

Conclusions

In addition to the sewer cleaning equipment discussed, there are other basic items such as trucks, pumps, air compressors, etc. There is one item, however, which although widely used is perhaps not in as general use as it should be; it is the ordinary type of electronic pipe finder. There is also available a smaller and extremely sensitive box locator. With this instrument, designed principally for the locating of small metallic objects, the

pin-pointing of buried property line cleanouts is the work of only a few minutes.

Manufacturers are to be commended on the ingenuity shown in the development of sewer cleaning equipment and on the generally high quality which they have been able to maintain. While there is still much room for improvement in both design and quality, much progress has been made during the last 25 years. It will be interesting to see what develops during the next 25 years.

SEWER MAINTENANCE IN SANTA CLARA COUNTY, CALIFORNIA *

By Stephen H. Goodman

District Manager, County Sanitation District No. 4, Santa Clara County, Calif.

County Sanitation District No. 4, Santa Clara County, Calif., operates a sanitary sewer system which consists of 120 miles of main and trunk sewers, 42 miles of lateral sewers, and three small pumping stations (150 gpm). It serves an area of approximately 26 square miles. The main and trunk sewers range in size from 6 in. to 24 in. Most of the pipe used is clay. The City of San Jose provides the main interceptor sewer and sewage treatment service on a contractual basis.

Value of Preventive Maintenance

Many articles have been written concerning preventive sewer maintenance. The values received from a well-planned and executed maintenance program can be summed up as follows:

1. Elimination of potential sewer stoppages that create hazardous and unhealthy conditions.
2. Reduction of the number of sewer stoppages that will occur and that require unscheduled work, including necessary overtime.
3. Reduction in the number of complaints from the public concerning odors, noisy manhole covers, vermin entering houses, and street cave-ins.
4. Provision of a basis for defense in lawsuits attempting to prove negligent operation of a sewerage system.
5. Extension of the useful life of a sewerage system by keeping its capacity to the maximum and by eliminating sewage gases that hasten the deterioration of the structures.

The utilization of a preventive sewer maintenance program (since 1952) in the operation of the county sewerage system has assured the benefit of many of the preceding points. Since start of the program, the number of sewer stoppages in main and trunk sewers has averaged 16 per year, and 11 per year in lateral sewers.

Preventive Maintenance Program

Briefly the preventive sewer maintenancee program consists of cleaning all main and trunk sewers 10 in. in diameter and smaller at least once every two years. A ribbed sewer cleaning ball controlled by a tag line is used. This is augmented with flexible rods and tools when heavy sediment restricts the progress of the ball. Sewers larger than 10 in. in diameter are inspected annually and cleaned with a sewer cleaning ball, or rods, when inspection reveals the need for cleaning.

Experience has shown that sewers 12 in. and larger in diameter are prac-

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tically self-cleaning when laid to a grade that will provide a velocity of 2 fps and used to at least 30 per cent of capacity. Attention is required only occasionally; when children throw debris down the manholes or when detrimental substances are disposed to the sewer system.

Sewers serving industrial and commercial establishments are inspected periodically and tested for the presence of explosive vapors or liquids and other detrimental substances. Sewers that show signs of vermin are baited with poisoned grain. Roots are either removed with the sewer cleaning ball, or in the case of larger roots, with flexible rods and a root-cutting tool. A chemical compound has been used to treat sewers where roots are the principal problem. However, the results are too recent to report anything satisfactory at this time.

Building sewers, from the buried cleanout at the property line to the main sewer, are maintained by the District when stoppages occur in them. This service is provided without direct cost to the property owner, provided the cleanout at the property line has been uncovered and the house plumbing checked.

Maintenance Personnel and Equipment

The preventive sewer maintenance program, as well as the unscheduled maintenance work, is performed by a trained crew made up of three maintenance men and a superintendent of maintenance and operation.

The crew is equipped with a pick-up truck, a water truck with cabinets for sewer ball cleaning equipment, a dump truck with tool box and 1,000 lb electric hoist, flexible sewer rods, tools, trailer-mounted turning engine, sewer balls (6 in. to 15 in. in diameter), rope reels, safety equipment, and minor hand tools.

Sewer Maintenance Cost

It is difficult to compare costs of sewer maintenance for various cities and districts because a uniform system of accounting is not followed. However, such costs are of interest. The cost of maintaining the sewer system of County Sanitation District No. 4, Santa Clara County, for the fiscal year 1955–56 totaled $32,250. This included salaries, supervision, overhead, equipment depreciation, and supplies. This amounts to an annual maintenance cost of $269 per mile of main and trunk sewers. However, since the District maintains some 42 miles of lateral sewers, this mileage should be included in the total length of sewers maintained. The annual cost of maintenance is then reduced to $202 per mile of main, trunk, and lateral sewers.

The use of sewer balls in the sewer cleaning program is still relatively new in the District and is reflected in the length of sewer that can be cleaned during a work day. The average length of sewer cleaned by the crew is approximately 1,500 ft, compared with reported footages up to 5,000 ft in other cities in California. Greater efficiency should be realized as the maintenance crew gains additional experience in the use of this type of sewer cleaning equipment. It is anticipated that the footage cleaned per day can be increased substantially.

Sewer Maintenance Records

As in any well-planned and executed system, a simple, yet effective, system of recording data pertinent to the maintenance of a sewer system is essential to a preventive sewer maintenance program. A visible card file system has been adopted for the recording of sewer maintenance data. The system consists essentially of three cards on which is recorded pertinent data concerning the description of the sewer system, maintenance performed, and the work to be performed.

Sanitary Sewer Inventory Card
In-Out Balance

Street *Inez Way*

Date	Description		Additions or Deductions		In-Out Balance	
	Job No.	Size	Footage	Value	Footage	Value
8-3-56	*191*	*6"*	*300*	*$816.00*	*300*	*$816.00*
Summary		*6"*			*300*	*$816.00*

FIGURE 1.—Sanitary sewer inventory card.

Inventory Card

Figure 1 is a reproduction of the sanitary sewer inventory card. An inventory card is maintained for each street within the District and entries are made as sewers are either added to or lost from the District's jurisdiction. Losses occur through annexation of areas within the District to cities maintaining and operating their own sewer systems. The inventory card is used for general accounting purposes, determination of insurance premiums, and planning purposes by the maintenance superintendent.

Maintenance Record Card

Data on maintenance work performed on a sewer is entered on the sanitary sewer maintenance record card (Figure 2). A card is maintained for each street containing a sewer, and weekly entries are made from information submitted in the maintenance crew's daily work report. The card is filed with the corresponding inventory card.

Over a period of years the card will provide a concise record of the maintenance work performed on any particular sewer and will point out recurring sources of trouble. A sliding indicator at the bottom right corner of the maintenance record card is set to the month during which the next maintenance work is to be performed.

Work Order Card

A work order card (Figure 3) is kept for each street and is filed behind the corresponding maintenance record card. The first of each month the work order cards are pulled from behind the maintenance record cards that have their indicators set for that particular month. The maintenance superintendent uses the cards to establish the daily work schedule for the maintenance crew. After the current maintenance work has beeen completed on a particular sewer, the maintenance superintendent reviews the sewer maintenance record of that sewer and notes on the work order card the date and description of the next work that he wants performed on the sewer. This procedure insures the projection of the preventive sewer maintenance program into the future, based on a concise history of maintenance work performed in the past. The work order card is then refiled and the indicator on the maintenance record card is set to the next scheduled date for maintenance work on the sewer.

Sanitary Sewer Maintenance Record

Date	Location	Work Cause	Flush	Ball	Rod	100 G Water	Ft	Men	Material	Equipment	Remarks
2-5-57	*MH 1-48-4 to MH 1-48-3*	*Routine*		√		*2*	*300*		—	*M.V. #28 #3 Sewer Ball*	—

Street *Inez Way*

Next Year	J	F	M	A	M	J	JL	A	S	O	N	D

FIGURE 2.—Sanitary sewer maintenance record card.

Sanitary Sewer—Work Order Card

Date	Location	Sewer		Description of Work to be Done	Remarks
		Size	Length		
2-57	*MH 1-48-4 to MH 1-48-3*	*6"*	*300'*	*Clean with sewer ball.*	*Completed 2-5-57*
3-57	*MH 1-48-4*			*Raise manhole frame and cover to grade.*	

Street *Inez Way*

FIGURE 3.—Sanitary sewer work order card.

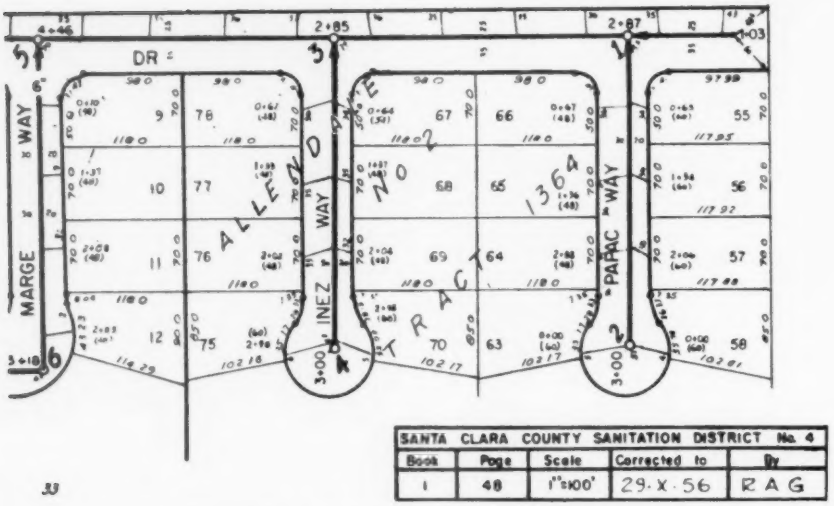
DR
MARGE WAY
INEZ WAY
PARAC WAY
ALLENDALE
SANTA CLARA COUNTY SANITATION DISTRICT No. 4
Book | Page | Scale | Corrected to | By
1 | 48 | 1"=100' | 29-X-56 | R A G

FIGURE 4.—Typical page from sewer map book.

Sewer Maps

An accurate record of the location and depth of sanitary sewers and their appurtenances is essential to a preventive sewer maintenance program. The sewerage system of the County Sanitation District is mapped on sheets 12 by 19 in. which are then bound into several books. One set of books is kept in the office, one set is furnished to the maintenance superintendent, and one set to the maintenance crew.

A typical page from the map books is shown in Figure 4. Each manhole, flushing inlet, and pump station is given a code number which establishes its location. For example, manhole 9-35-6 can be located by referring to Map Book 9, page 35, and noting the location of manhole 6 on the map. This short number is used to designate the location of maintenance work performed and is recorded on the record card. The sewer maps are also used to determine the depth to sewers, distance between manholes, and location of lateral cleanouts.

Summary

A well-planned and executed preventive sewer maintenance program is essential to the efficient and economical operation of a sewer system. County Sanitation District No. 4, Santa Clara County, Calif., has an effective preventive sewer maintenance program of proved value. A visible card record system and sewer maps are used as aids in planning and executing the program.

SLUDGE DIGESTER OPERATION AT BRIGHTON, NEW YORK *

By John Laird

Superintendent, Brighton Sewer District No. 2, Brighton, N. Y.

The Allen's Creek sewage treatment plant serves Sewer Districts No. 1 and No. 2 of Brighton, N. Y., and Sewer District No. 1 of Pittsford, N. Y. The plant is jointly owned and is operated under terms of a joint contract by Brighton Sewer District No. 2 (George H. Bush, Superintendent). The plant serves a drainage area of 3,970 acres and a population of 20,000, according to the 1956 house count.

Treatment Facilities

The original plant was constructed in 1928 and consisted of an Imhoff tank, a trickling filter, secondary settling tanks, and open sludge drying beds. The design was for an ultimate population of 10,000. The areas served by the Allen's Creek plant underwent the rapid postwar population expansion common to many suburban areas. The plant, therefore, was enlarged in 1951 to serve a population of 20,000. The additions included a primary settling tank, a trickling filter, a secondary settling tank, separate sludge digesters, and covered sludge drying beds.

Sludge digestion facilities consist of two 35-ft diameter tanks; each has a capacity of 30,000 cu ft and a 30-ft sidewater depth. This provides 3 cu ft per capita sludge digestion capacity. Both tanks have floating covers with gas collection domes. There is an external heat exchanger with recirculation pump, and high and low suction inlets and outlets are provided. The high sludge inlet discharges in the gas dome on top of the scum blanket. A ball-type positive displacement pump handles all sludge pumping. There is a supernatant selector and sight gauge for each tank. The piping arrangement is identical for each tank, thus making it possible to use the tanks either in parallel or in series. Only series or stage digestion has been used to date.

Initial Operation

The digesters were tested for leaks early in 1954 by filling with water. This water was left in and brought up to an operating temperature of approximately 90° F. The first sludge was added to the tanks in mid-February 1954, and the first tank was filled with sludge in about 30 days. The initial pH of the sludge was about 6.0 and remained at this level for several months. It was evident that the digesters were "stuck" in the acid stage. Therefore, on July 12 lime was added to the digesters at a rate of about 200 lb per day. By August 20 the pH had risen to 6.8 and the waste gas burner was lit. On August 23 the mixture in the digesters boiled over with a vengeance, and there was foam knee-deep all around the tanks for a month.

The digesters finally quieted down and during the winter of 1954–55 they seemed to be functioning properly under the then normal operating conditions. Normal operating conditions consisted of holding the temperature in the primary digester at 92° F. The circulation pump was operated intermittently, according to the need for heat. This meant that the pump ran about 25 per cent of the time.

Scum

By the winter of 1955 it was apparent that the formation of scum in

* Presented at the Spring Meeting, New York Sewage and Industrial Wastes Assn.; Lake Placid, N. Y.; June 17–18, 1957.

the primary digester was not being controlled. Early in 1956 heat and gas production decreased materially and about 4 ft of heavy inert fibrous material formed at the top of the digester. For a week efforts were made to break up this layer of floating solids. A portable 4-in. centrifugal pump was set up and recirculated supernatant liquor was discharged on top of the scum through hatches in the floating cover. Some of the scum was broken up and sank, only to rise to the surface after a few hours. Finally, the primary digester was allowed to rest and the other tank was operated as the primary.

At this time the program of digester operation was evaluated and certain changes were made. The temperature in the primary digester was slowly brought up to 100° F and the sludge circulation pump was operated continuously. Sludge was pumped for about 2 hr each day in an attempt to circulate the tank from bottom to top. A 2-in. line was run from the circulation pump to the scum-breaking piping on the floating cover. This line replaced the water line formerly used for this purpose. Supernatant was then circulated daily on to the scum layer. Wooden paddles were also used to break up any scum formation around the edge of the floating covers. Lime was added only as necessary for pH control. Only a little lime has been added since March 1956. The sludge in the primary digester is kept as thoroughly mixed as possible, especially around the scum layer.

The scum problem has been solved to date. During 1956, scum was never more than a few inches in depth, and has stayed soft and moist. The digesters have been performing in a satisfactory manner, as evidenced by the data in Table I.

TABLE I.—1956 Digester Performance

Item	Quantity
Raw sludge to digesters:	
Total (cu ft)	268,000
Daily avg (cu ft)	700
Dry solids (%)	6.7
Volatile solids (%)	64
Dry volatile solids (lb/day)	1,660
Digested sludge withdrawn:	
Total (cu ft)	36,160
Dry solids (%)	9.3
Volatile solids (%)	41.9
Volatile solids reduction (%)	84.7
Gas production:	
Total (1,000 cu ft)	5,413
Daily avg (1,000 cu ft)	14.8
Per capita, daily (cu ft)	0.74
Per pound volatile solids (cu ft)	8.9

Mechanical Problems

In addition to the operational difficulties, there also were mechanical troubles. Although the digesters were to be ready in 1952, they were not placed in operation until 1954. During the first year of operation a mercury switch on the heat exchanger shorted and the equipment overheated, necessitating a complete overhaul by the manufacturer. In 1956 the circulation pump had to have major repairs and the sludge pump had minor repairs.

In March 1957 the operator was unable to transfer sludge from the primary digester to the secondary digester. An unsuccessful attempt was made to open up the sludge drawoff line using water pressure. Finally the digester was dewatered by lowering the contents as far as possible through use of the supernatant drawoff and then placing a portable plunger pump on the digester roof to pump out the rest of the sludge. It took more than a month to empty the digester. The cause of the stoppage was an accumulation of about a truck load of stringy and fibrous rags. These rags were caught between the sludge drawoff and the center pipe supports.

To add to the trouble, the supernatant selector had somehow wedged under the cover when the digester level was lowered and was bent out of shape. Since it was unsafe to use a cutting torch in the tank, a man was lowered

into the tank by rope so the selector could be cut off its support with a hacksaw. The supernatant selector has been replaced and the underside of the floating cover has been painted. The sludge drawoff line will be shortened so that it will not be close to the bottom of the digester or to the three pipe supports in the center of the tank.

On the whole, the equipment provided has been acceptable and the operations are satisfactory. The use of 6-in. sludge piping is questioned; 8-in. pipe is preferred for use throughout the plant. The operation of restricted-area plug valves on the sludge lines has definitely been unsatisfactory.

The operation of the digesters at 100° F seems to give the best results. The high temperature (mesophilic range) and constant mixing in the primary unit are an answer to normal scum problems. More effective mixing would be an asset. It is believed that careful digester feeding and control will eliminate much of the pH problem, and lime should be added only when necessary to relieve an acid condition.

TIPS AND QUIPS

Quarter Century Operators' Club

Three new members were added to the roll of the Quarter Century Operators' Club during 1957, although the passing of William M. Piatt and William C. Hamm reduced the roster.

Newly qualified members approved by the Federation Board of Control on October 6, 1957 are:

Michael A. Green, Dearborn, Mich.
Harry C. Lewis, San Antonio, Texas
E. F. Miltner, Wichita, Kans.

It is planned that a roster of all Club members will be prepared and mailed to the members during 1958. The roster in October included 55 living and 14 deceased members.

It is believed that there are many operators in the Federation who are eligible for membership in the Club. However, unless they make themselves known it is impossible to extend a special invitation to join. Operators should recognize the honor of being a member of the Club and thus serve to strengthen the interest of operating personnel in the Federation.

To be eligible for membership in the Quarter Century Operators' Club the candidate must have been in full-time resident charge of the operation of a sewage treatment plant for 25 years prior to the date of his admission to the Club. He need not now be engaged in treatment plant operation, but he should have a continuing interest.

All eligible personnel are urged to contact the chairman of the Club: Henry Van Der Vliet, P. O. Box 281, Rutherford, N. J.

Wet Sludge Incineration

Concentrated wet raw sludge is proposed to be incinerated at the $100 million sewage treatment facility of the Allegheny County Sanitary Authority. This facility is under construction and will serve the City of Pittsburgh and 69 suburban municipalities.

The raw sludge will be preheated to 95° F and stored for three to five days. A concentrated sludge, averaging 18 per cent total solids, is then produced by flotation. This sludge will be mixed with fine coal and incinerated. Completion of the system is expected early in 1959.

Resistant Organism

About 2,000 times as much radiation is required to kill a bacterial spore as is fatal to man.

Laboratory Equipment *

Giant Spatula

A general purpose laboratory tool that makes an excellent scraper for cleaning out incrusted laboratory containers, stirring large quantities of material, or measuring out reagents is a large stainless steel spatula. Two models of the spatula (ChemiScraper) are available. One is 12 in. long with 2-in. blades; the other is 18 in. long with 2½-in. blades.

Chain Clamp

A new chain clamp quickly secures laboratory equipment with a diameter of 3 in. to 6½ in. One end of the nickel-plated, plastisol-dipped steel chain is permanently attached to a movable slider. The free end is looped around the glassware, attached to the hook on the other side of the clamp body, and tightened with a large nonslip knob.

Utility Relocation

Fourteen states have passed laws which would reimburse utility departments for relocation costs because of highway construction or relocation.

Mail Courses

The International Correspondence Schools, 1001 Wyoming Ave., Scranton, Pa., has available correspondence in sewage treatment plant operation.

True

Public water supplies and public sewerage systems provide the most satisfactory sanitary facilities.

Barrel Rack

A steel rack has been designed to permit the handling and stacking of loaded or empty barrels and drums. The drum rack supports two loaded barrels and simplifies the stacking of pairs of containers to any practical height (Figure 1). The rack (and container) is designed to be readily handled by a fork lift truck.

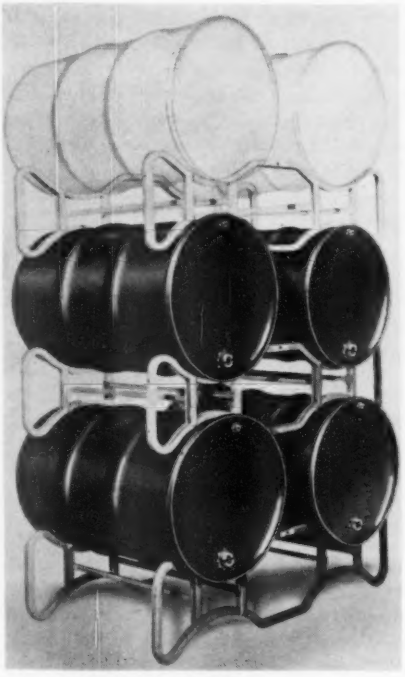

FIGURE 1.—Steel barrel rack.

Drums are protected from the damage resulting from stacking drum upon drum. Bunged drums are easy to get at for drawoff. One rack will support 7,500 lb in 18-gage drums and 14,000 lb in 16-gage drums.

Further information is available from the Pressed Steel Division, Republic Steel Corp., 6100 Truscon Ave., Cleveland, Ohio.

Handy Suction Cup

A small suction cup (about 2 in. in diameter) on a short handle makes a handy gadget to lift out the balls from the ball check valves of piston pumps when clogging occurs. Its use eliminates a messy part of the operation.

* From Fisher Scientific Company, 717 Forbes St., Pittsburgh 19, Pa.

Federation Affairs

THIRTIETH ANNUAL MEETING SETS RECORDS

A return to historic Boston was observed to celebrate the 30th Annual Meeting of the Federation, Oct. 7–10, at the Statler Hotel. Boston had previously been the meeting site in 1949 when a successful gathering numbered 821 registrants. To demonstrate the growth of the Federation the 1957 meeting saw a record attendance of 1,363, an increase of more than 65 per cent over the meeting eight years earlier. The previous meeting high was the 1,345 recorded at Atlantic City in 1955. A wide distribution of home bases was apparent in the registration, wherein representatives of 41 states, the District of Columbia, Canada, Puerto Rico, and six foreign countries were recorded.

The success of the meeting was helped by an excellent technical program and the attractive location. Appreciation is due the host, the New England Sewage and Industrial Wastes Association, with the Local Arrangements Committee headed by Frank L. Flood. Able assistance was given by John S. Bethel, Jr., who acted as Vice-Chairman.

President Emil T. Jensen called the meeting to order Monday morning, Oct. 7. Following the invocation, an official greeting from Mayor of Boston John B. Hynes was delivered by Mr. John D. Brown, City Greeter. President Jensen commented on the future of the Federation and its responsibilities. The business portion of the morning session was ended with the report of the Executive Secretary-Editor, Ralph E. Fuhrman. His report announced to the membership that four new member associations (two in the United States and two foreign) had been admitted to Federation membership. With these, there is only one state in the United States without member representation.

Technical Program

A well-rounded program of technical papers was developed by the Program Committee, headed by George E. Symons. Some session adjustments were incorporated in the program schedules to accommodate the material for presentation. Two concurrent sessions were included to allow the maximum coverage of subjects of pertinent interest. The Research Symposium, for the third time, was well received. Significant reports of Public Law 660 were heard in the Sewage Works Panels. A lively discussion from a large audience indicated the interest in the Operators' Forum. The Industrial Wastes Forum was stimulated by active audience participation.

The Laboratory Scientists' Breakfast again was a popular event with those interested in control measures. In all, 38 attended and found insufficient time to discuss the topics of current interest.

A new event was the Industrial Wastes Breakfast, attended by 36 The highlight of this breakfast was a report by President-elect Watson on the plans and aims of the Federation regarding industrial wastes during 1958.

The technical program was as announced in the "Thirtieth Annual Meeting Preview" (see THIS JOURNAL, **29**, 9, 1085; Sept. 1957). Technical program papers are to be published in the 1958 Journal, beginning with this issue.

Meeting Publicity

While the Federation has long realized the value of meeting publicity, the 1957 meeting marked a milestone in this activity. By the use of an attended press room and the services of professional public relations personnel, active press coverage was given to the meeting. Four Boston papers carried six news items on the meeting. Assistance in this activity was given by Val Laughner Associates of Boston, provided through the generosity of Fay, Spofford and Thorndike, Engineers, of Boston.

In addition, releases were sent to the newspapers in the home communities of award winners and officers. Representatives of seven trade journals used the press room facilities in preparation of copy for publication.

The future will see further activities in this direction as guided by the newly formed Public Relations Committee.

Entertainment Events

The current interest in square dancing was appropriate for the Family Night, Monday, in the Statler Hotel Ballroom where the New England Folk Festival was held. Attractive native costumes were the "order-of-the-evening" as participants enjoyed the well-arranged program. Demonstrations by two New England square dance groups and three foreign groups were highlights of the evening.

The Federation Luncheon, attended by more than 350, was featured by an address from Mr. Laurence B. Whittemore, Chairman of the Board of Directors of the Brown Company, in which he outlined some of the natural resources problems in New England.

The Annual Federation Awards Dinner in the Imperial Ballroom attracted about 800 members and guests. President Jensen presented the awards and introduced the new officers. President-elect Watson spoke of the challenge to the Federation in providing maximum progress in pollution control. The dinner was followed by dancing by an exceptionally large number of those attending the meeting.

Ladies' Entertainment

The meeting attraction to the ladies was demonstrated by the record attendance of 301. Appropriate to the group, a busy and entertaining schedule was arranged by the local Ladies' Entertainment Committee. A get-acquainted tea, for which the New England Sewage and Industrial Wastes Association was host, was held Monday afternoon in the Women's City Club to set the stage for the friendly gathering.

A highlight of the meeting was an all-day visit to Old Sturbridge Village where a delightful luncheon was enjoyed in the surroundings of a restored New England village of the colonial period.

A co-feature of particular attraction to the ladies was a Wednesday morning bus tour of historic Boston. Among the stops made were the home of Paul Revere, Old North Church, Bunker Hill, and the frigate, "Constitution." Ample time was allowed for individual sightseeing and shopping trips in Metropolitan Boston.

Inspection Trips

Features in Boston of interest to the technical gathering were scheduled as inspection trips. On Wednesday afternoon the well-known Nut Island Sewage Treatment Plant was visited by bus. This plant has received considerable attention and was a valuable addition to the schedule of those attending the meeting.

To provide maximum flexibility in the inspection arrangements there were two alternate trips offered Wednesday morning. The William T. Sedgwick Laboratories of Sanitary Science and the Pilot Plants at Massachusetts Institute of Technology were open to those interested to demonstrate the current research in the sewage and industrial wastes field.

The second alternative was to join the ladies group in the historic tour of Boston. The response of the large numbers taking advantage of the scheduled inspection trips was enthusiastic approval of the programming.

Manufacturers' Exhibit

The Water and Sewage Works Manufacturers Association accounted for the traditional exhibit of new equipment, products, and process developments. Exhibits were conveniently located in two rooms on the same floor. All available space was utilized. An interesting growth comparison is seen when it is considered that at the 1949 meeting in Boston there were 29 exhibits using 50 booth spaces, while at the 1957 meeting there were 45 exhibitors occupying 85 spaces.

BOARD OF CONTROL MEETS AT BOSTON

The 30th Annual Meeting of the Federation Board of Control at Boston, Mass., heard reports on the continuation of the Federation's rapid growth of recent years. An important factor in the 1957 membership growth was the admission to Federation membership of four new Member Associations—two in the United States and two in foreign countries. The new Member Associations include the Utah Sewage and Industrial Wastes Association, the Mississippi Sewage and Industrial Wastes Association, and the Israel Sewage Association. The petition of the New Zealand Sewage and Industrial Wastes Association was approved subject to a favorable recommendation of the Organization Committee. (This recommendation has since been received.)

The Board of Control received and acted upon the recommendations contained in many committee reports. Some of the important actions taken by the Board as a result of these reports and recommendations of the directors are the following:

1. Approval was given for the preparation and publication of a 10-year index for the Federation Journal for the years 1949–58. It is anticipated that this volume will be available for distribution early in 1959.

2. Final authorization was given for the joint publication of the manuals, "Design and Construction of Storm and Sanitary Sewers," and "Design of Sewage Treatment Plants," both of which are nearing completion. These manuals are being prepared jointly by committees of the Federation and the Sanitary Engineering Division of the American Society of Civil Engineers.

3. Early printing was authorized for the Federation manual, "Sewer Maintenance."

4. A mail ballot was agreed upon as the appropriate method for the Board to act upon the recommendations of the Constitution and Bylaws Committee when it makes its final report. This committee has been considering new provisions to the Federation Bylaws to strengthen Federation ties to organizations having only section affiliation with the Federation and expects to report on the results of its deliberations in the near future.

5. The formation of a new subcommittee for the Sewage and Industrial Wastes Practice Committee, to be known as the "Industrial Wastes Manual Subcommittee," was authorized. This group will review the industrial wastes manuals now available with the purpose of determining what contributions of value could be made by the Federation in the area of new manual preparation.

6. The formation of a Public Relations Committee was authorized as a result of the Board's appreciation of the need for increased attention to the public relations aspects of all Federation activities.

7. A Nuclear Wastes Committee was authorized and appointed.

At the October 6 Board Meeting, 41 officers and directors answered the roll call. All Constitutional Advisory Committees were represented at both the October 6 and 10 meetings. Similarly, 43 officers and directors were present for the October 10 meeting.

New Officers

The following officers were elected on October 6 for the terms indicated:

President: Kenneth S. Watson, Schenectady, N. Y., to October 1958.

Vice-President: William D. Hatfield, Decatur, Ill., to October 1958.

Treasurer: W. W. DeBerard, Chicago 2, Ill., to October 1958.

Director-at-Large: J. E. McKee, Pasadena, Calif., to October 1960.

1957 Awards

The following honors and awards, as conferred by the Board, were presented or announced by President Jensen at the Annual Awards Dinner on October 9:

Elected to Honorary Membership were Victor M. Ehlers of Austin, Texas, Chief Engineer of the Texas State Department of Health since 1915, and Morris M. Cohn of New York, N. Y., Editor of *Wastes Engineering*. Both men have rendered important services to the sanitary engineering profession and have given generously of their time and talents to forwarding the work of the Federation.

The Harrison Prescott Eddy Medal was earned by Werner N. Grune, James V. Carter, Jr., and J. Peter Keenan for the research work at the Georgia Institute of Technology, as presented in their paper, "Development of a Continuous Gas Chromatographic Analyzer for Sludge Digestion Studies" (THIS JOURNAL, **28**, 12, 1433; Dec. 1956).

The George Bradley Gascoigne Medal was conferred on Thomas T. Hay, superintendent of the sewage treatment plant at Racine, Wis., for his plant-operation contribution, "Air Flotation Studies of Sanitary Sewage" (THIS JOURNAL, **28**, 1, 100; Jan. 1956).

The Industrial Wastes Medal was awarded to F. E. Dryden, P. A. Barrett, J. C. Kissinger, and W. W. Eckenfelder, Jr. for their work at the Cherokee Plant of Merck & Co., published under the title, "High-Rate Activated Sludge Treatment of Fine Chemical Wastes" (THIS JOURNAL, **28**, 2, 183; Feb. 1956).

For his many contributions to the sanitary engineering profession through his leadership in the Federation of Sewage and Industrial Wastes Associations, various committees and boards, for his work at all levels, local, state, national and international in the interest of his fellow man, and for his inspiring record as a teacher and educational administrator, Earnest Boyce, Ann Arbor, Mich., was awarded the 1957 Charles Alvin Emerson Medal.

Nominations for the 1957 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: Joseph L. Crockett, Jr. (Alabama); Leigh Owen Gardner (Arizona); Alvin A. Appel (California); Gordon Henry Baker (Canadian Institute); O. J. Muegge (Central States); David B. Smith (Florida); Friedrich Wilhelm Sierp (Germany); Myron K. Nelson (Kansas); Robert A. Greene (Michigan); Lindon J. Murphy (Missouri); Henry F. Munroe (New England); Louis J. Fontenelli (New Jersey); Raymond W. Hess (New York); Carl D. McGuire (Ohio); Robert O. Sylvester (Pacific Northwest); and Howard T. Reuning (Pennsylvania).

Nominations for the 1957 William D. Hatfield Awards, for outstanding sewage treatment plant operation, were confirmed by the Board as follows: Owen D. Waldrep (Alabama); Ed-

ward E. Bayze (Arizona); Edward O. Sampson (California); Douglas J. Davidson (Canadian Institute); Ronald A. Kronewitter (Central States); Clifford M. Courson (Florida); Lyle Cunningham (Kansas); J. C. Marshall (Michigan); Walter C. Anderson (New England); Anthony J. Maeri (New Jersey); Uhl T. Mann (New York); Andrew J. Wahl (Pacific Northwest); and K. H. Hendrickson (Pennsylvania).

Membership

The Secretary reported that the aggregate Active and Corporate membership of the Associations comprising the Federation was at a record high of 7,680 on September 30, 1957, a gain of 694, or 10 per cent, for the year. Many Member Associations made excellent gains, although some losses were reported. Increased membership was recorded by 30 Member Associations, whereas 8 recorded no increase or a loss.

The total number of Associate Members increased to 78 as of September 30, 1957.

The Florida Association, with an increase of 104 members, won the numerical increase contest over the determined efforts of the Canadian Institute (90) and New Jersey Association (71).

The Rocky Mountain Association took the percentage increase prize with a net gain of 91.4 per cent, showing a substantial portion of the increase during the closing weeks of the competition. They were followed by the Kansas (63.6 per cent) and Florida (40.8 per cent) Associations as runners-up.

Petitions for the authorization of new Member Associations were received during the year from Israel, Mississippi, Utah, and New Zealand. These are the first petitions received since the admission of the Nebraska and Swedish Associations in 1952. The increase in Member Associations to the new total of 42 will better serve the interests of the Federation in the United States and abroad.

Financial

The operating budget for fiscal 1958 is balanced at $123,200, a modest increase of $1,400 over the previous year.

Audited net worth of the Federation at the end of 1956 was $90,190.78, a substantial increase over 1955.

Toronto in 1962

The Meeting Place Committee recommended, and the Board approved, Toronto, Canada, as the official 1962 meeting place for October 8–11, 1962 at the Royal York Hotel. Previously announced and approved meeting sites are:

1958, Detroit, Mich., Sheraton-Cadillac Hotel, Oct. 5–9.
1959, Dallas, Texas, Hotel Statler-Hilton, Oct. 11–15.
1960, Philadelphia, Pa., Philadelphia-Sheraton, Oct. 2–6.
1961, Milwaukee, Wis., Schroeder Hotel, Oct. 9–12.

A new invitation was received verbally from the New Jersey Sewage and Industrial Wastes Association (Atlantic City) and referred to the Meeting Place Committee. Invitations already on hand from Member Associations were: Florida (Miami Beach), Georgia (Atlanta), Iowa (Des Moines), Kansas and Missouri (Kansas City, Mo.), Nebraska (Omaha), New York (New York City), Pacific Northwest (Seattle), and Rocky Mountain (Denver).

Bedell and Hatfield Award Nominations

The accompanying schedule of Bedell and Hatfield Award nominations was approved by the Federation Board of Control on October 6, 1957. In accordance with the 1957 report the award schedule for the current three-year period is included. Attention is called to the listing of the number of members by individual associations for indications of growth and changes in eligibility for award nominees.

Bedell and Hatfield Award Schedule

(Date of Award is year submitted to Board of Control)

Member Association	Members		Nominations Per 3 Years	Future Schedule*		
	9-30-56	9-30-57		1958	1959	1960
Alabama	45	51	1	—	—	1
Arizona	40	42	1	—	—	1
Arkansas	58	50	1	—	1	—
California	611	650	3	1	1	1
Canadian Institute	472	562	3	1	1	1
Central States	693	711	3	1	1	1
Dakota (North & South)	37	32	1	—	1	—
Federal	76	80	1	1	—	—
Florida	255	359	2	1	—	1
Georgia	103	98	1	—	1	—
Germany	38	40	1	—	—	1
Iowa	132	124	1	1	—	—
IPHE (England)	38	29	1	—	—	1
ISP (England)	134	122	1	1	—	—
Israel†	—	20	—	—	—	—
Kansas	110	180	1	—	—	1
Kentucky-Tennessee	180	183	1	1	—	—
Louisiana	15	17	1‡	1‡	—	—
Maryland-Delaware	70	75	1	—	1	—
Michigan	396	433	2	1	—	1
Mississippi†	—	1	—	—	—	—
Missouri	55	61	1	—	—	1
Montana	37	36	1	—	1	—
Nebraska	74	66	1	1	—	—
New England	390	400	2	—	1	1
New Jersey	255	326	2	1	—	1
New York	621	640	3	1	1	1
New Zealand†	—	—	—	—	—	—
North Carolina	159	174	1	1	—	—
Ohio	376	401	2	—	1	1
Oklahoma	55	60	1	—	1	—
Pacific Northwest	311	335	2	1	—	1
Pennsylvania	503	523	3	1	1	1
Puerto Rico	43	55	1	—	1	—
Rocky Mountain	58	111	1	—	1	—
South Carolina	47	45	1	1	—	—
Sweden	91	104	1	1	—	—
Swiss	15	17	1‡	—	—	1‡
Texas	198	216	1	1	—	—
Utah†	—	26	—	—	—	—
Virginia	125	130	1	—	1	—
West Virginia	80	95	1	—	1	—
Totals	6986	7680		18	17	18

* Schedules for 1959 and 1960 based on membership as of Sept. 30, 1957.

† New member associations award schedules to be determined by Board of Control at 1958 Federation meeting.

‡ Year eligible to petition for one nomination.

KENNETH S. WATSON NEW PRESIDENT

Kenneth S. Watson, Consultant, Water Management and Waste Control for the General Electric Company, Schenectady, N. Y., became the 18th President of the Federation at the organization meeting of the 1958 Board of Control, held at Boston, Massachusetts, on October 10, 1957.

After graduation from West Virginia University with the degree of Bachelor of Science and Master of Science in Chemical Engineering, with sanitary options, Mr. Watson served as chemical engineer and later as Executive Secretary-Engineer of the West Virginia Water Commission. He subsequently served a year with the Ohio River Valley Water Sanitation Commission as Assistant Director. In his association with the General Electric Company he has served in various capacities during the development of the company's water management and waste control program, of which he is now consultant.

During World War II, Mr. Watson commanded an Army engineer combat battalion and is presently a Lt. Colonel in the Reserve Corps.

In connection with his professional duties, Mr. Watson has held a number of responsible positions with various governmental groups. He was a member of the Interstate Commission on the Potamac River Basin and chairman of its technical committee. As a member of the Ohio River Valley Water Sanitation Commission he represented the State of West Virginia. He is a member and past chairman of the National Technical Task Committee on Industrial Wastes and a member of the National Sanitary Engineering Research Advisory Committee of the U. S. Public Health Service. He is also a member of the Advisory Committee on Air Pollution for the State of New York.

Mr. Watson's professional affiliations include membership in the American Water Works Association, American Chemical Society, Air Pollution Control Association, and the Manufacturing Chemists' Association Water Pollution Abatement Committee. As a member of the American Institute of Chemical Engineers he was a chairman of the Pollution Control Engineering Committee, and is one of the three trustees representing the institute on the American Sanitary Engineering Intersociety Board.

Mr. Watson has written extensively on water management and waste treatment, having published more than 30 papers in this field. In 1955 he received the Industrial Wastes Medal from the Federation. He received the Charles Agar Memorial Award in 1956 from the New York Sewage and Industrial Wastes Association for another industrial wastes contribution. In May 1956 he was designated by the Secretary of State to serve as engineer-adviser to the United States delegation to the World Health Assembly meeting in Geneva, Switzerland.

In addition to serving the Federation in various capacities, Mr. Watson has completed service as Vice-President of the Federation (1956–57). He is now a member of the Executive, Finance, Industrial Wastes, General Policy, Joint Policy, Meeting Place, and Honorary Membership Committees.

WILLIAM D. HATFIELD ELECTED VICE-PRESIDENT

William D. Hatfield, Superintendent, Sanitary District of Decatur, Illinois, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 6, 1957.

Dr. Hatfield brings to his Federation office practical experience in sewage treatment plant operation. His contact with municipal and industrial waste problems related to an expanding municipal operation will make him sympathetic to the needs of the Federation membership.

A 1914 graduate of Illinois College with a Bachelor of Science degree, Dr. Hatfield received the Master of Science and Doctor of Philosophy (Chemistry) degrees from the University of Illinois.

Prior to acceptance of his present position in 1924, Dr. Hatfield was assistant chemist and bacteriologist with the Illinois State Water Survey (1915–18), asistant professor of organic and physical chemistry at Montana State College (1919–20), and superintendent of filtration at Highland Park, Mich. (1921–23).

His interest in sewage treatment operation and control, laboratory methods, and industrial waste recovery and treatment has been manifested by his active participation on the joint editorial board for the 8th, 9th, and 10th Editions of "Standard Methods." In the work on the 10th Edition he represented the Federation. He has been active on the Federation's Joint Committee with Committee D-19 on Standard Methods of the American Society for Testing Materials. He is also on the Joint Committee on Uniformity of Methods of Water Examination.

In 1945 the Federation created the William D. Hatfield Award to recognize outstanding annual sewage works operations reports. Dr. Hatfield received the Charles Alvin Emerson Medal from the Federation in 1953. He is a member of the Quarter Century Operators' Club. He has received the Thomas Fitch Rowland Prize and the Rudolph Hering Medal from the American Society of Civil Engineers.

Dr. Hatfield served as Vice-President (1944) and President (1945) of the Central States Sewage Works Association. He was Director from Central States on the Federation Board of Control (1952–54). At present he is a member of the Executive, Meeting Place, and Standard Methods Committees of the Federation.

Editorial

NEW JOURNAL ABBREVIATIONS

With this issue of SEWAGE AND INDUSTRIAL WASTES, the reader will observe the use of simplified abbreviations. These follow the scheme of the American Standards Association (ASA) as originally approved in March 1941 * and conform generally to those in use by the *Journal American Water Works Association.*

Periods are omitted except where confusion would result. The general use of these abbreviations in manuscripts will be helpful in their review and writers are urged to use them consistently to help the effort of standardization. The following list is not intended to be all inclusive but illustrates the principles on which extensions will be based.

acre-foot	acre-ft	feet per hour	fph
alternating-current (adj.)	a-c	feet per minute	fpm
ampere (s)	amp	feet per second	fps
ampere-hour (s)	amp-hr	Figure	Fig.
average	avg	foot	ft
barrel (s)	bbl	gallon (s)	gal
Baumé	Bé	gallons per acre per day	gpd/acre
billion gallons	bil gal	gallons per day	gpd
biochemical oxygen demand	BOD	gallons per hour	gph
brake horsepower	bhp	gallons per second	gps
British thermal unit	Btu	gallons per square foot per day	gpd/sq ft
calorie	cal	gram	g
centimeter (s)	cm	horsepower	hp
counts per minute	cpm	horsepower-hour (s)	hp-hr
cubic centimeter (s)	ml	hour (s)	hr
cubic feet per day	cfd	inch (es)	in.
cubic feet per hour	cfh	inches per second	ips
cubic feet per minute	cfm	indicated horsepower	ihp
cubic feet per second	cfs	inside diameter	ID
cubic foot (feet)	cu ft	kilocycles	kc
cubic inch	cu in.	kilogram (s)	kg
cubic meter (s)	cu m	kilometer (s)	km
cubic yard (s)	cu yd	kilovolt (s)	kv
degree (s)	deg	kilovolt-ampere (s)	kva
degree Centigrade	°C	kilowatt (s)	kw
degree Fahrenheit	°F	kilowatthour (s)	kwhr
diameter	diam	linear foot	lin ft
direct-current (adj.)	d-c	liter (s)	l
dissolved oxygen	DO	logarithm (common)	log
feet	ft	logarithm (natural)	$\log_e$
feet per day	fpd		

* "Abbreviations for Scientific and Engineering Terms," American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y. Price $0.50.

maximum ..... max
maximum permissible concentration ..... MPC
meter ..... m
microcurie (s) ..... μc
micromicrocurie (s) ..... μμc
micromicron (s) ..... μμ
micron (s) ..... μ
miles per hour (s) ..... mph
milliampere (s) ..... ma
millicurie (s) ..... mc
milligram (s) ..... mg
milligrams per liter ..... mg/l
milliliter (s) ..... ml
millimeter (s) ..... mm
millimicron (s) ..... mμ
million electron-volts ..... Mev
million gallons ..... mil gal
million gallons per acre per day ..... mgd/acre
milliroentgens ..... mr
minimum and minute (s) ..... min
molar (concentration) ..... M
molecular weight ..... mol wt
most probable number ..... MPN
normal (concentration) ..... N
Number (s) ..... No.
ounce (s) ..... oz
outside diameter ..... OD
parts per million ..... ppm
pound (s) ..... lb
pounds per square foot ..... psf
pounds per square inch ..... psi
pounds per square inch absolute . psia
quart (s) ..... qt
radiation absorbed dose ..... rad
revolutions per minute ..... rpm
revolutions per second ..... rps
roentgen (s) ..... r
roentgen equivalent, man ..... rem
roentgen equivalent, physical .... rep
second (s) ..... sec
specific gravity ..... sp gr
specific heat ..... sp ht
square ..... sq
square centimeter (s) ..... sq cm
square foot (feet) ..... sq ft
square inch (es) ..... sq in.
volt (s) v
volt-ampere (s) ..... va
watt (s) ..... w
watthour (s) ..... whr
week (s) ..... wk
yard (s) ..... yd
year (s) ..... yr

Reviews and Abstracts*

A Study on the Biological Treatment of Sewage by Activated Sludge. By Sladecek Vladimir. Scientific Papers from Inst. of Chemical Technology, Prague, Poland, pp. 1–84 (1957).

A pilot plant of the Kessener type of activated sludge process was operated at Prague for about two years with domestic sewage. Periodic chemical analyses and biological examination of samples were made. It was concluded that bulking of activated sludge is accompanied with or preceded by a significant rise in the quantity of organisms in the activated sludge. The relationship between pH, alkalinity, and nitrification is emphasized once again. It is contended that the optimum temperature for purification of sewage (80 to 90 per cent) is between 7° and 13° C. Above and below this temperature purification fluctuates and falls off. The best purification is obtained in the presence of 200 to 500 cu mm per liter of organisms. At values above and below this the purification is not satisfactory.

H. Heukelekian

The Removal of Anionic Syndets by Biological Purification Processes—Observations at Luton and Letchworth. By F. W. Roberts. *Water and Waste Treatment Jour.*, **6**, 7, 302 (1957).

At Luton sewage works, high quality effluents have been obtained during periods when sewage contained a high concentration of syndets. Treatment consists of sedimentation followed by activated sludge, a trickling filter, and rapid sand filters, which serve as strainers. The final effluent has a BOD of 5.3 ppm, suspended solids of 4.2 ppm, and anionic syndets of 2.8 ppm. The sewage contained 10.4 ppm of syndets. Sedimentation removed 26.7 per cent, activated sludge 20.8 per cent, trickling filters 39 per cent and the sand filter 30 per cent of the residual syndet coming to each unit. The removal of syndet was not necessarily associated with the removal of organic impurity.

At Letchworth, after sedimentation one portion of the settled sewage is treated by means of activated sludge (12 hr detention) and the remainder by trickling filters; rate of application is 50 gpcd (Imp.). Both processes produce good quality nitrified effluents. With a syndet concentration of 9.4 ppm in the settled effluent, the activated sludge effluent had 3.0 ppm syndet and the trickling filter effluent 4.1 ppm.

H. Heukelekian

Quantitative Determination of Organic Nitrogen in Water Sewage and Industrial Wastes. By J. B. Morgan, J. B. Lackey and F. W. Gilcreas. *Anal. Chem.*, **29**, 833 (1957).

Mercuric sulfate is reported as being a better catalyst than copper sulfate for aiding sulfuric acid in the digestion of organic nitrogen samples. The mercuric sulfate catalyst gives a faster and more complete recovery of nitrogen from organic compounds than does copper sulfate. The ammonia is distilled into boric acid and back titrated with standard sulfuric acid.

R. S. Ingols

Radioactive Tracer Study of Sewage Field in Santa Monica Bay. By Ralph L. Ely, Jr. *IRE Trans., Nuclear Science*, **4**, 1, 49 (Mar. 1957).

A use of scandium-46 (85 day half-life) for measuring the dilution of sewage in Santa Monica Bay is described. It was reported that the radioactive tracer en-

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

abled *in situ* measurements of dilution of sewage effluent by sea water to 1 part in 10,000. Twenty curies of radioactivity were injected into the sewage effluent over a period of 1 hr at a time when the sewage flow-rate was about 5,000,000 gph. A watertight scintillation probe was trailed behind the oceanographic vessel at a depth of 3 ft. The detector consisted of a 1½ by 1½ in. NaI (Tl) crystal.

CONRAD P. STRAUB

Disposal of Atomic Waste at Windscale. ANON. *Atomics*, 7, 12, 437 (Dec. 1956).

Radioactive gases from the first industrial atomic site in the United Kingdom are discharged at 1/10 of the tolerance levels agreed by the International Commission on Radiological Protection. Extensive tests over a five-year period have proven conclusively that there is no harm to marine or human life from the discharge of the Station's liquid effluent via a two-mile pipeline into the Irish Sea. During a period of 14 months, more than 1,500 samples of seaweed, fish, and sand were collected; the results showed that no harmful effect could be suffered by fish, fishermen, bathers, or those accidentally swallowing seawater, sand, or seaweed. PHEA (1957)

CONRAD P. STRAUB

Toxicity of Synthetic Detergents to Rainbow Trout. BY D. W. M. HERBERT, G. H. J. ELKINS, H. T. MANN AND J. HEMENS. *Water and Waste Treatment Jour.*, **6**, 9, 394 (1957).

In clean well-oxygenated water, 3 ppm manoxol O.T. (alkylaryl sulfonate) produced a 50 per cent mortality of rainbow trout in about 12 weeks. The residue of these detergents after the sewage has been treated biologically are much less toxic than the original materials.

H. HEUKELEKIAN

The Application of the Activated Sludge Process to the Further Purification of Biological Filter Effluent. BY P. F. B. VOSLOO AND P. O. FINSEN. *Water and Waste Treatment Jour.*, **6**, 8, 348 (1957).

The results of laboratory experiments on the aeration of effluents from trickling filters in contact with the sludge produced from the filter are presented. Such a process would lead to the interposition of an aeration tank between the trickling filter and secondary sedimentation tank with provisions for the return of settled sludge. Improvement might be expected in the settling property of the sludge and the removal of colloidal matter.

The results reported in the paper deal primarily with the oxidation of ammonia and show that aeration of filter effluent with trickling filter sludge brings about highly effective oxidation of ammonia to nitrate and substantial reductions in oxygen absorbed. The oxidation of ammonia proceeds at a constant rate until all the ammonia is converted. In general, increasing the concentration of sludge increased the oxidation of ammonia. The pH of the mixture will be affected depending on the alkalinity of the filter effluent and degree of nitrification. In continuous feed experiments, the lowest pH value obtained was 5.4, indicating that at about this pH nitrification ceases. At these low pH values the sedimentation of the sludge produced was poor.

Substantial reductions in bacterial numbers were obtained by this method of treatment.

H. HEUKELEKIAN

Determination of Low Concentrations of Radioactive Cesium in Water. BY B. KAHN, D. K. SMITH AND C. P. STRAUB. *Anal. Chem.*, **29**, 1210 (1957).

Three methods for determining cesium are given. Because of technical problems with the methods, only small samples of river water are used for comparatively high level radioactivity.

R. S. INGOLS

Determination of Phenolic-type Compounds in Water and Industrial Waste Waters. BY E. F. MOHLER, JR. AND L. N. JACOB. *Anal. Chem.*, **29**, 1936 (1957).

The article compares the five most widely used methods for determining small amounts of phenolic-type compounds found in water. The techniques were evaluated in regard to sensitivity, precision, accuracy, interferences, reagents, and time requirements. Of the colorimetric procedures, the 4-aminoantipyrine technique is the fastest, most precise, and accurate even at the low concentration values found in drinking water. The direct use of ultraviolet adsorption offers considerable promise. A complete discussion of the antipyrine technique is given.

R. S. INGOLS

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S-13

Proceedings of Member Associations

ARKANSAS WATER AND SEWAGE CONFERENCE

The 26th Annual Meeting of the Arkansas Water and Sewage Conference was held at Little Rock, Ark., March 18–20, 1957 in conjunction with the annual short course for water and sewage works operators. A record attendance of 237 was reported. The 1958 Meeting will be held at Fayetteville, Ark., March 24–28, 1958.

Officers for 1957–58 are:

Chairman: Foster Burba, Pine Bluff.
Vice-Chairman: Nall Brantley, Forrest City.
Secretary-Treasurer: C. W. Oxford, Fayetteville.

C. W. Oxford,
Secretary-Treasurer

IOWA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 39th Annual Meeting of the Iowa Sewage and Industrial Wastes Association met at Des Moines, Iowa, June 19–21, 1957. This was a change from the usual meeting month which has been September. Attendance was somewhat lower, even though the meeting place was centrally located. However, several factors may account for this, and the 1958 meeting is also planned for June.

The technical program featured papers devoted to industrial wastes, the problems of communities not having treatment facilities, and sewage treat-

(*Continued on page 26a*)

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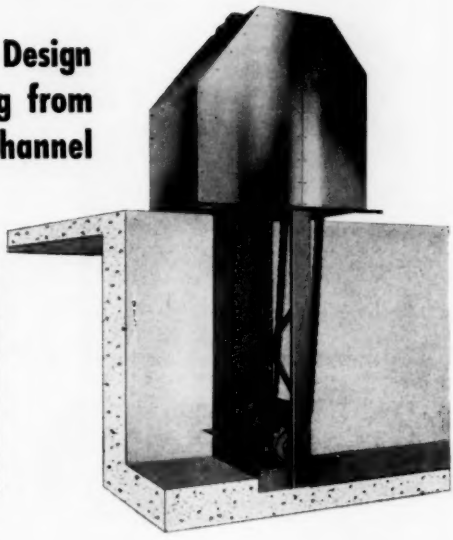
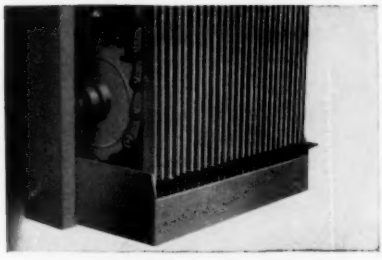
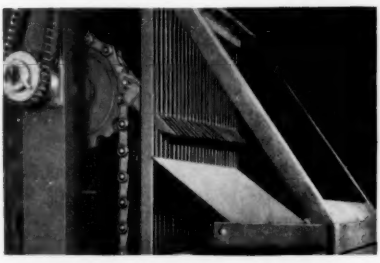




Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

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North Side Sewage Treatment Plant, Chicago, Ill.
Hickam Air Force Base, Honolulu, T. H.
West Palm Beach, Fla.
Kylan Corporation, Brunswick, Ga.
Addison, Ill.
Genesco, Ill.
Glen Ellyn, Ill.
North Side Sewage Treatment Plant, Skokie, Chicago, Ill.
Mission Township, Kan.
Arkansas City, Kan.
Cincinnati, Ohio.
Oragrande, N. M.
San Angelo, Texas.
Tryon Park Sewage & Pump Station, Rochester, N. Y.
Hudson River State Hospital, Poughkeepsie, N. Y.
Millville, N. J.
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ment plant operation. Operating problems and the future role of the operator were discussed at the Operator's Breakfast. The meeting closed with an inspection trip to the Des Moines sewage treatment plant.

At the annual business meeting the following officers were elected:

President: H. S. Smith, Muscatine.
Vice-President: Ralph Briley, Ames.
Secretary-Treasurer: L. F. Skorczeski, Marshalltown.

More than 30 ladies were present during the three-day meeting. Plans are being made by them for the formation of an auxiliary.

L. F. Skorczeski,
Secretary-Treasurer

PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 29th Annual Conference of the Pennsylvania Sewage and Industrial Wastes Association was held at Pennsylvania State University, University Park, Pa., on August 28–30, 1957. Approximately 310 members and guests were registered, including about 50 ladies; a new record attendance for this meeting. The annual banquet was attended by nearly 230 persons.

The excellent technical program was well balanced between the fields of sanitary sewage and industrial wastes. Concurrent sessions on the opening day featured round tables for sewage works operators and industrial wastes interests. Two breakfast sessions were scheduled, one on control analyses and the other on industrial wastes. Active participation in the technical program was encouraged through the scheduling of time for open discussion following each paper. The concluding session featured a panel on trickling filter performance with the panelists reporting on filter operation at municipal and industrial wastes treatment facilities.

Federation Vice-President K. S. Wat-

(*Continued on page 28a*)

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son presented the Bedell Award to Howard T. Reuning, Engineer, New York and Pennsylvania Company, Inc., Ridgway, and the Hatfield Award to King H. Hendrickson, Superintendent, sewage treatment plant, Beaver Falls.

At the annual business meeting, the formation of sections within the Pennsylvania Member Association was discussed and tentative approval given.

Officers elected for 1957–58 were as follows:

President: Bernard S. Bush, Wilkes-Barre.
First Vice-President: Harry W. McElhaney, Meadville.
Second Vice-President: Samuel I. Zack, Harrisburg.
FSIWA Director (1959): T. R. Haseltine, Pittsburgh.
Secretary-Treasurer: J. R. Harvey, Meadville.

J. R. Harvey,
Secretary-Treasurer

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 30th Annual Meeting of the Central States Sewage and Industrial Wastes Association, held at the Sherman Hotel, Chicago, Ill., June 26–28, 1957, was highlighted by the technical program and by the Langdon Pearse Memorial Banquet. The technical program emphasized industrial wastes practice with talks by representatives of paper, oil refining, and steel industries. Public Law 660, particularly the grant-in-aid provisions for sewage treatment plant construction as applied in the Central States group, was discussed. The effect of salt brine on trickling filter slimes was also the subject of an interesting paper.

The annual banquet was dedicated to the memory of Langdon Pearse, one of the founders of the Central States Member Association. An illuminated scroll commemorating his achievements in the field of sanitary engineering and expressing appreciation for his efforts on behalf of the Association was presented to Mrs. Pearse. Federation President Emil Jensen brought the greetings of the Federation and presented the Hatfield Award to I. G. Knoebel, Superintendent of the sewage treatment plant, Belleville, Ill., and the Bedell Award to W. W. Mathews, Superintendent, Gary Sanitary District, Gary, Ind. Association President W. E. Ross presented the Radebaugh Award for the best paper by a member in the preceding year to Henry T. King of the Sanitary District of Chicago for the paper entitled, "Mechanics of Oxygen Absorption in Spiral Flow Aeration Tanks" (This Journal, **27**, 8, 894; 9, 1007; 10, 1123; 1955).

Merit Awards for membership promotion activity were presented to Jess Dietz of Illinois, Frank Wraight of Indiana, George Schroepfer and Donald Thimsen of Minnesota, and Gerald Lawton of Wisconsin. Operation Report Awards went to Donald Henn, DeKalb Sanitary District, DeKalb, Ill., R. A. Kronewitter, Mishawaka, Ind., and C. W. Bogenhagen, Fond du Lac, Wis.

The Local Arrangements Committee was headed by L. E. Langdon and E. Hurwitz and the Program Committee by Lee Kraus. The social hours sponsored by the Water and Sewage Manufacturers Association contributed greatly to the success of the program.

Officers elected were:

President: A. Paul Troemper, Springfield, Ill.
First Vice-President: R. W. Frazier, Oshkosh, Wis.
Second Vice-President: Lyle Smith, Minneapolis, Minn.
Third Vice-President: Paul Brunner, Fort Wayne, Ind.
FSIWA Director (1960): W. W. Mathews, Gary, Ind.
Secretary-Treasurer: Scott Linsley, St. Paul, Minn.

George F. Bernauer,
Secretary-Treasurer

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(Continued through page 36a)

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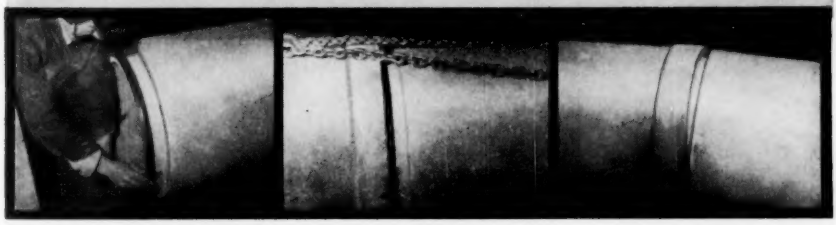

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When you plan your new plant or the expansion of your present one, be sure to plan a place for W & T Dry Chemical Feeders as well as Chlorinators. W & T Feeders are used for every type of dry feeding problem found in water and sewage treatment plants.

W & T makes both volumetric (volume measurement) and gravimetric (weight measurement) feeders. There is a feeder for any size job, from small equipment to measure out ounces, to accurate giants capable of handling thousands of pounds per minute.

To find out more about W & T Dry Chemical Feeders, write for bulletin S-123. Or let us know the type of feeder problem you have, so we may send publications describing the W & T equipment best suited for your job.

WALLACE & TIERNAN INCORPORATED

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